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CONTRACT TRIAL OF THE UNITED STATES SEA-GOING BATTLE SHIP *IOWA.*

BY PASSED ASSISTANT ENGINEER J. M. PICKRELL, U. S. NAVY.

The *Iowa* is a twin screw, armored, sea-going battle ship, and was built by the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa., the designs having been furnished by the Navy Department. The contract was signed on February 11, 1893, the price being $3,010,000, and the time for completion three years. The speed guarantee was sixteen knots per hour, to be maintained successfully for four consecutive hours, during which period the air pressure in the fire rooms was not to exceed one inch of water, the vessel to be weighted to a mean draught of twenty-four feet. It was stipulated that the contractors should receive a premium, over and above the contract price of the vessel, at the rate of $50,000 per quarter of a knot for the amount maintained in excess of the contract speed, and that there should be deducted from the contract price a sum at the rate of $25,000 per quarter of a knot for the amount by which the vessel failed to reach the contract speed.

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 4 feet throughout the length of the double bottom, and 3.5 feet forward and abaft the double bottom. The thickness of the outer keel plate is $\frac{3}{4}$ inch, of the inner, $\frac{5}{8}$ inch, and of the vertical keel, $\frac{1}{2}$ inch. The outer bottom plating is $\frac{5}{8}$ inch thick, and the inner bottom plating, $\frac{3}{8}$ inch.

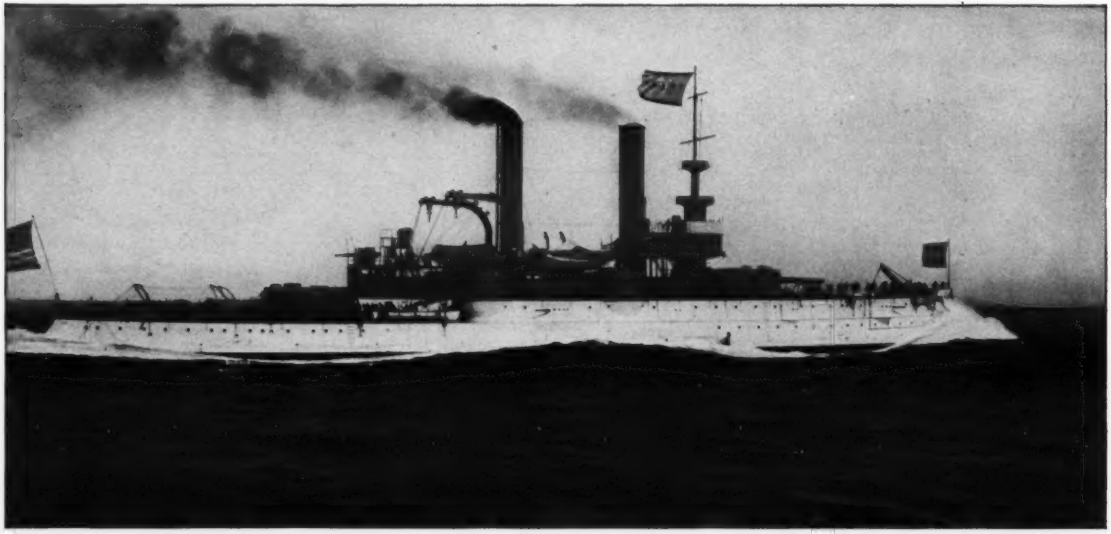
The ship is divided into 284 water tight compartments. The double bottom extends from frame 21 to frame 79, a distance of 232 feet, and runs up to the armor shelf. It is 3 feet 3 inches in depth amidships and is divided into 12 water tight compartments. Double coffer dams, each 36 inches wide, extend forward and abaft the diagonal armor on both sides of the ship from the protective to the berth deck. A single coffer dam, 36 inches wide, and 36 inches above the deck plating, extends on the berth deck forward and abaft the casemate armor on both sides of ship. The coffer dams are filled with compressed cellulose. The transverse bulkheads are carried through the coffer dams to divide them into water tight compartments.

Hold.—In the hold abaft the engine compartments and forward of the boiler compartments are: Coal bunkers, trimming tanks, engineer stores, hydraulic pump rooms, bread room, fixed ammunition, 8-inch shell rooms and magazines, 12-inch magazine and lower hold.

After Platform.—Here are 12-inch magazine, handling room and shell room, 8-inch magazine, fixed ammunition, equipment and ordnance store rooms and steering engine.

Forward Platform.—This contains 12-inch magazine, shell rooms and handling room, general stores, upper hold and trimming tanks.

Orlop Deck.—On the orlop deck, forward and abaft the athwartship armor, are: Store rooms, fresh water tanks and tiller room; and within the citadel, coal bunkers, ventilating fans, dynamo room, 8-inch turret turning machinery, central station for voice pipes and telephones, auxiliary magazines for 8-inch, 4-inch and rapid fire guns. Outboard on each side is an armored passage extending from bulkhead at frame 31 to bulkhead at frame 68.



U. S. S. "IOWA."

FROM A COPYRIGHTED PHOTOGRAPH BY W. H. RAU, PHILADELPHIA, 1897.

Inboard of the armored passage, and extending the same length, is an ammunition passage.

Berth Deck.—On the berth deck are the living quarters, coal bunkers, the refrigerating plant, engineer's workshop, log room, &c.

There are 30 coal bunkers with a total capacity of 1,795 tons at 43 cubic feet to the ton. They are distributed as follows: 18 in the hold with a capacity of 1,402 tons; 4 on the orlop deck with a capacity of 149 tons; 8 on the berth deck with a capacity of 244 tons. They are filled through chutes and trunks fitted between decks. The trunks are fitted with shunt doors at the top where they pass through the coal bunkers on the berth deck, and vertical doors at the bottom, so that the coal can be passed from these bunkers into the trunks, and through the orlop deck into the bunkers below. Armored shutters are fitted in the trunks where they supply coal to the bunkers through the orlop deck.

There are three ash chutes on each side, on the outside of the vessel, semi-oval in shape. The upper ends of the chutes extend above the main deck, where hoppers are formed inside. Trolley ways for carrying the ash buckets are fitted under the deck beams above, leading from the ash hoists to the chutes.

Drainage System.—For draining the compartments, there is a 14-inch main drain pipe on the port side, and a 7½-inch secondary drain pipe on the starboard side, extending in the double bottom compartments under the engine rooms, and in the bilges of the boiler rooms. There are six cisterns located in pairs in the double bottoms, one pair each under the after parts of the engine, after boiler and forward boiler compartments, respectively. Each pair is divided by the vertical keel plate, and there is a sluice gate, worked from the berth deck, connecting the port and starboard cisterns of each pair. The cisterns have each an opening in the inner bottom, which is fitted with a strainer and a combined automatic ball float, non-return and screw-down valve worked from the berth deck.

The main drain pipe has branches connecting the suctions of both main circulating pumps with all the cisterns. The branches to the cisterns have sluice gates worked from berth deck. The secondary drain pipe has similar connections to those of main

drain—only the branches to cisterns have lever check valves worked from berth deck, instead of sluice gates—and the suction connections are to manifolds by which seven of the steam and two of the deck pumps may be used instead of the main circulating pumps.

The seven auxiliary steam pumps have, through manifolds, a separate suction from one of each pair of cisterns. The main circulating pumps have a direct bilge connection, each in its own compartment.

There are two bilge wells in each engine room and one in each boiler room, and a crank pit suction in engine room, all of which connect through manifolds with the suctions of seven auxiliary steam pumps.

The double bottom compartments, and the compartments forward and aft of them, have separate suctions, which connect through manifolds in engine and boiler rooms with seven auxiliary steam and two deck pumps. Compartments above the armored decks have, in general, no permanent drains fitted, but are cleared of water by means of portable pumps worked by hydraulic pressure from the fire mains. The waste water from the bath and wash rooms is led by pipes to tanks located in the coal bunker between Nos. 4 and 6 fire rooms, and is pumped overboard by a Davidson pump, with steam cylinder $4\frac{1}{2}$ inches in diameter, water cylinder 4 inches in diameter, and a stroke of 6 inches.

The boats carried are as follows:

1 40-foot vedette steam launch.
1 33-foot steam cutter.
1 30-foot steam cutter.
2 30-foot whale boats.
1 30-foot whale boat gig.
1 33-foot sailing launch.
1 30-foot barge.
1 28-foot cutter.
1 24-foot cutter.
2 20-foot dinghies.
2 balsas.
2 punts.

Length between perpendiculars, feet	360
on L.W.L., feet	360
over all (including rudder), feet and inches	362–6¾
Beam, extreme, feet and inches	72–2¾
at L.W.L., feet and inches	72–2¾
Ratio of length to beam	4.99
Depth, from top of main deck beams to top of floor, feet and inches	31–11½
Height of superstructure above main deck beams, feet and inches	7– 6
Draught, normal, forward, feet and inches	23–10
aft, feet and inches	24– 2
mean, feet and inches	24– 0
Displacement, corresponding to normal draught, tons	11,340
per inch, at L.W.L., tons	46
Area of immersed midship section to L.W.L., square feet	1,637
L.W.L. plane, square feet	19,300
Center of gravity of L.W.L. plane, forward of frame No. 48, feet	.4
buoyancy above bottom of keel, feet	13.25
forward of frame No. 48	2.2
gravity above bottom of keel, feet	25.11
Transverse metacenter above center of buoyancy, feet	16.62
Longitudinal metacenter above center of buoyancy, feet	350
Coefficient of fineness on extreme dimensions	.630
of midship section	.944
of L.W.L.	.733
Cylindrical coefficient	.668
Number of frames	93
water tight compartments	283

ARMOR.

The armor consists of a side belt of Harveyized nickel steel, extending through the machinery and boiler spaces and to the bases of the 12-inch gun turrets. It is 3 feet above, and 4 feet 6 inches below the 24-foot load water line. The outside surface conforms to the shape of the vessel, with a thickness of 14 inches from the top of armor to 12 inches below the load water line, from which point it tapers to 7 inches at the top of armor shelf. At each end of this water line belt, there is an athwartship bulkhead 12 inches thick, thus completing the armored citadel. The citadel is covered with an armored deck of nickel steel 2¾ inches thick, while forward and abaft the citadel, the protective decks are of 3-inch nickel steel. Above the 14-inch side belt and extending to the main deck, there is a casemate of 5-inch armor, made up of two ½-inch plates and one 4-inch plate.

The armor of the turrets for the 12-inch guns is of nickel steel 15 inches thick, and the bases of the turrets are protected by barbettes of the same thickness of nickel steel. The armor of the turrets of the 8-inch guns is 6 inches thick, the top plating, 2 inches, and the sighting towers, 5 and 3 inches thick. The bases of the 8-inch turrets are protected by barbettes with armor 8 inches thick on the outer sides and 6 inches thick on the inboard sides.

The armored protection of the 4-inch guns is 5 inches thick, made up of two inner thicknesses of ½ inch each and an outer thickness of 4 inches. The armored protection for the 6-pounder guns on the main deck is 2 inches thick. For the protection of the 1-pounders at the ends of the vessel, the plating is increased to a total thickness of 2 inches in wake of the ports, so that it will act as a shield.

The conning tower is located above the superstructure deck; it is of steel, forged hollow in one piece, 10 inches thick, and has an internal diameter of 6 feet 11 inches.

An armored tube, 7 inches thick and 12 inches in internal diameter, extends from the conning tower to the armored deck and protects the electric wires, voice tubes, connections to engine room telegraphs, steering gear and engine tell-tales.

ARMAMENT.

The main battery consists of four 12-inch breech-loading rifles, 35 calibers, mounted in pairs in two balanced turrets. The turrets are on the fore-and-aft center line of the ship, the forward one being on the upper deck and the after one on the main deck; eight 8-inch breech-loading rifles, 35 calibers, mounted in pairs in the four turrets on the superstructure; and six 4-inch breech-loading rifles, two on each side, on the main deck within the superstructure, and two aft on the bridge deck.

The secondary battery consists of twenty 6-pounder Hotchkiss rapid fire guns; four 1-pounder Hotchkiss rapid fire guns; and four light machine guns in the military tops.

The 12-inch turrets are worked by hydraulic power, and the guns by hand power; the 8-inch turrets by steam power, and the

guns by hand. The 4-inch guns are worked by hand on central pivot carriages.

There are four tubes for Howell torpedoes, two on each side, discharging directly from the berth deck. Attached to each tube, there is a steam turbine for imparting energy to the torpedo fly wheel, and causing the latter to revolve at the rate of 15,000 revolutions per minute.

The armament throws a weight of projectile from the battery, in broadside at one discharge, of 4,560 pounds; and at one complete discharge of the battery, of 5,722 pounds.

MAIN ENGINES.

There are two vertical, inverted, direct-acting, triple expansion engines placed abreast of each other in separate water tight compartments, the H.P. cylinders being forward.

Each cylinder is supported by an inverted Y frame on one side, and by two hollow, forged steel, cylindrical columns on the other. Only the I.P. and L.P. cylinders are steam-jacketed on the sides and bottom, the H.P. being fitted with working liners only. There are no starting valves on the cylinders, provision being made for starting the engines by admitting live steam to the receivers. The relief valves for the cylinders are placed on the valve chest casings, on connections between the steam and exhaust sides of the main valves. There are two receivers for each engine, consisting of exhaust pipes and valve chests, the safety valves of which are set at 80 pounds for the I.P. and at 30 pounds for the L.P. The main valves are of the single-ported piston type, there being one for each H.P., two for each I.P. and four for each L.P. cylinder. They are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson type with double bar links. There are no independent cut-off valves, but provision is made to cut off in each cylinder, varying from .5 to .7 of the stroke, by means of a block to which the suspension links are attached, which block can be moved by hand screw gear in a slot in the end of the arm on the reversing shaft.

The main pistons are steel castings, dished, and are each fitted

with two packing rings, 1¼ inches wide and ⅜ inch thick. The piston and connecting rods are of forged steel. The crossheads are of forged steel, and each has a manganese bronze slipper, the sliding faces of which are fitted with white metal. The crosshead guide to take the thrust when going ahead is of cast iron bolted to the inverted Y frame. The back of the guide is recessed and covered with wrought iron plates to form a passage for circulation of water. Cast iron lips are bolted on each side of the go-ahead guide to take the thrust when backing. The eccentrics are of cast iron. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing one by through bolts in slotted holes. The eccentric straps are of composition, faced with white metal, and the eccentric rods of forged steel. The I.P. and L.P. valve stems have manganese bronze crossheads which take hold of the link blocks directly. Each engine bed plate consists of three sections of steel castings.

The reversing gear consists of a steam cylinder, 16 inches in diameter, and a hydraulic controlling cylinder, 8 inches in diameter, the pistons of which are on the continuation of the same rod. This rod is secured to a crosshead which connects with the arm on the reverse shaft. There is a by-pass valve on the hydraulic cylinder on the continuation of the steam valve stem. These valves are worked by a system of differential levers, the primary motion being derived from the hand lever on the working platform, and the secondary motion, from a pin on the reversing arm, the ports being so adjusted that the reversing engine follows the motion of the hand lever and is firmly held when stopped. There are two plug cocks, forming a locking device, connecting the ends of the hydraulic cylinder, and there is a pump, 2 inches in diameter and 4 inches stroke, for reversing by hand. The supply pipe of the hydraulic cylinder is the discharge of the pump, and the discharge from the hydraulic cylinder is to a reservoir with which the pump suction connects. By this arrangement the hand pump is always in gear.

There is a double cylinder, simple, horizontal turning engine, with cylinders 7 inches in diameter and 7 inches stroke, secured

to the deck above at entrance of each shaft alley. It drives a worm wheel on the forward end of the H.P. crank shaft by means of worm gearing and a second worm; the latter is made to slide on a feather key, and is held in place by a collar below and a removable key above it. A ratchet is fitted to the shaft of the engine for turning by hand.

Each main engine is fitted with a disc stop valve 15 inches in diameter, having a screw stem and a balance piston, and a butterfly throttle $17\frac{7}{16}$ inches in diameter. The main steam pipes are of copper and, when above 10 inches in internal diameter, are strengthened with steel bands 6 inches apart.

In both engine rooms there are distributing oil tanks, supplied from the main oil tanks by a Blake duplex pump, steam cylinders 2 inches in diameter, oil cylinders $1\frac{1}{4}$ inches in diameter, stroke $2\frac{3}{4}$ inches. The tanks are fitted with overflow pipes back to main tanks. Distributing pipes lead to the various manifolds which are fitted with adjusting valves, and from the manifolds, tubes lead to the various parts to be lubricated. The suction pipe of the pump is fitted with a strainer.

Cylinders, number for each engine	3
H.P., diameter, inches	39
I.P., diameter, inches	55
L.P., diameter, inches	85
Stroke of pistons, inches	48
Valves, H.P. (one for each cylinder), diameter, inches	$15\frac{1}{2}$
I.P. (two for each cylinder), diameter, inches	$22\frac{1}{4}$
L.P. (four for each cylinder), diameter, inches	20
Balance pistons, H.P., diameter, inches	$5\frac{1}{2}$
I.P., diameter, inches	8
L.P., diameter, inches	$7\frac{1}{2}$
Valve stems, H.P. (1), diameter, inches	$2\frac{3}{4}$
H.P. (1), diameter through valve, inches	$1\frac{3}{4}$
I.P. (2), diameter, inches	$2\frac{7}{8}$
I.P. (2), diameter through valve, inches	$1\frac{3}{4}$
L.P. (4), diameter, inches	$2\frac{7}{8}$
L.P. (4), diameter through valve, inches	$1\frac{3}{4}$
Main steam pipe ($14\frac{1}{2}$ inches diameter) area cross section, square inches	165.13
Exhaust pipes to I.P. cylinder (2) (13 inches H.P. end, 14 inches I.P. end) area of cross section, square inches	265.46 307.88
L.P. cylinder (4), 15 inches I.P. end, (8) $13\frac{1}{2}$ inches L.P. end, area of cross section, square inches	696.84 1,145.12

Exhaust pipes to condenser (2) (21 inches diameter) area of combined cross sections, square inches	692.72
Volume swept by H.P. piston (mean), per stroke, cubic feet	32.53
I.P. piston (mean), per stroke	65.34
L.P. piston (mean), per stroke, cubic feet	156.97
Net area of I.P. to H.P. piston	2.00
L.P. to I.P. piston	2.40
L.P. to H.P. piston	4.82
Clearances of H.P. cylinders, per cent.....top, 19.75; bottom,	17.74
I.P. cylinders, per cent.....top, 12.35; bottom,	13.37
L.P. cylinders, per cent.....top, 16 03; bottom,	15.43
Piston rods, diameter, inches	$7\frac{3}{4}$
length from piston to crosshead, feet and inches	6–$10\frac{7}{8}$
Connecting rods, length from center to center, feet	8
diameter of upper end, inches	$7\frac{1}{2}$
diameter of lower end, inches	$8\frac{1}{2}$
crosshead bolts (2), diameter, inches	$4\frac{1}{2}$
crank pin bolts (2), diameter, inches	$4\frac{1}{8}$
Crossheads, surface (ahead), square inches	540
(backing), square inches	445 5
pins, diameter, inches	10
length, inches	16
Reversing gear, steam cylinder, diameter, inches	16
controlling cylinder, diameter, inches,	8

Shafting and Bearings.—The crank, line, thrust and propeller shafting is hollow and of forged steel. The crank shaft of each engine is in three interchangeable sections, the cranks placed at angles of 120 degrees, and for the ahead motion follow in the order H.P., I.P. and L.P. There is one section of line shafting of nickel steel to each engine and supported on two bearings. The propeller shafts are fitted with a composition casing from inboard the stern tube stuffing box to the propellers; they extend far enough inboard to allow the inboard stern bearings to be withdrawn without moving the shafts. The shaft coupling bolts are finished to fit the holes snugly. They are put in from the after side of the coupling and are set up on the forward side with a wrought iron nut and split pin.

Each thrust bearing is of cast iron of the horse shoe pattern. The end and side walls of the pedestal form an oil trough inside of which, both forward and aft the horse shoes, is a composition bearing lined with white metal for taking the weight of the shaft.

The cap of this bearing is of cast iron lined with white metal. There is an oil cup in the top of each horse shoe, from which there is an oil hole to each collar, the white metal being channeled for the distribution of the oil. At each end of the bearing, there is a divided stuffing box and gland to prevent the escape of oil. The pedestal is bolted to a cast iron sole plate, fitted with wrought iron wedges at each end of the pedestal for adjusting the bearing fore and aft.

Crank shafts, diameter, inches	16
axial hole, inches	7½
coupling discs, diameter, inches	30
thickness, inches	3½
bolts in one flange (6), diameter, inches	3¾
journals, diameter, inches	16
length, inches	18
length of each section, feet and inches	9–6
Crank pins, diameter, inches	16
length, inches	19
axial hole, inches	7½
Crank webs, width, inches	17
thickness, inches	10
Thrust shafts, diameter, inches	15¾
diameter of coupling disc, inches	30
axial hole, inches	7½
collars, number each shaft	11
diameter, inches	23½
thickness, inches	2
distance between, inches	3¾
surface, total for both engines, square inches	5,054.06
length, feet and inches	13–9
Line shafts, diameter, inches	15¾
axial hole, inches	9¾
diameter of coupling discs, inches	30
length, feet and inches	32–10
Propeller shafts, diameter, inches	17½
axial hole, inches	12
diameter of coupling discs, inches	30
length, feet and inches	44–7½
Stern bracket bearing, length, inches	44¾
diameter, inches	19½
tube bearing, length, forward, inches	35½
aft, inches	42

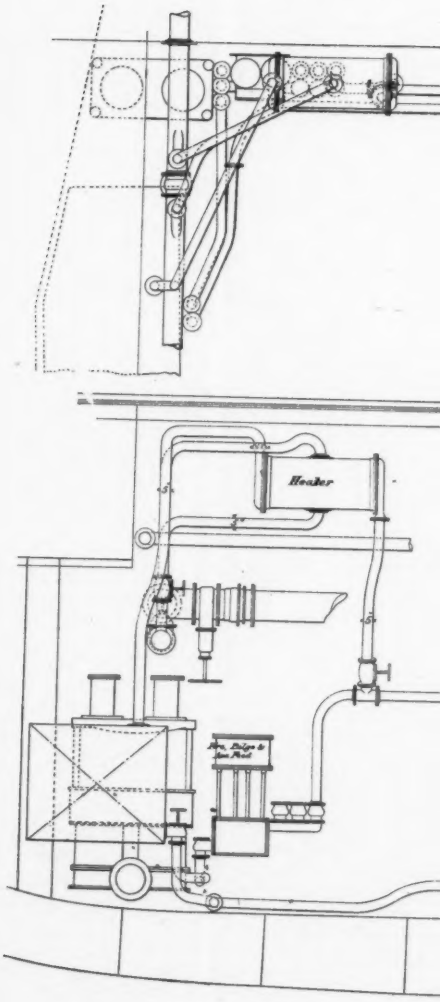
Main Condensers.—There are two main condensers, one for each engine, of cast composition, in three sections. The circulating water passes through the tubes. Baffle plates are fitted to direct the steam over the tubes, and plates are provided for supporting the tubes and also to act as baffle plates.

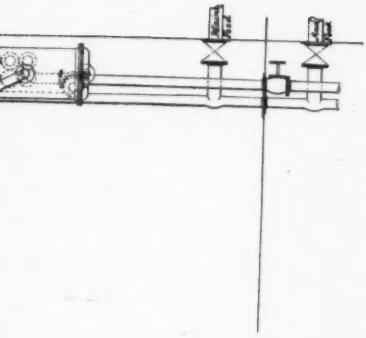
Diameter of shell (inside), feet	6
Thickness of shell, inch	$\frac{7}{16}$
Length over heads, feet and inches	12–2
Tubes, diameter (outside), inch	$\frac{5}{8}$
length between heads, feet	12
thickness, No. 18 B.W.G., inch	.049
number in each condenser	4,107
Cooling surface, each condenser, square feet	8,062
total, square feet	16,124
Ratio of total cooling to total heating surface	1 to 1.493

Main Air Pumps.—For each main engine there is a Blake double, vertical, single-acting air pump. The steam cylinders are placed directly over the pump cylinders, the pump rods and piston rods forming a continuous length. The pumps are connected by means of a beam, which is pivoted at its center, and from which beam the valve motion is actuated. The beam receives its motion through links swinging from crossheads on the pump and piston rods.

Diameter of steam cylinders (2), inches	12
pump cylinders (2), inches	25
Stroke, inches	18
Diameter of piston rods, inches	$2\frac{1}{4}$
pump rods, inches	4
Kind and diameter of pump valves (vulcanized rubber), inches	$5\frac{1}{2}$
Ratio of volume swept by L.P. piston, net area, per stroke, to that of the two air pump buckets, per stroke	15.55
Ratio of volume swept by one L.P. piston to that of the two buckets of one air pump per minute, on full power trial.....starboard, 70.36, port,	72.81

Main Circulating Pumps.—For each main condenser there is a centrifugal, double-inlet circulating pump, which is arranged to draw from the sea, bilge and main drain pipe, and to discharge either into the condenser or directly overboard. It is driven by a vertical, single cylinder engine. Each pump is capable of discharging 11,000 gallons of water per minute from the bilge.


Heater

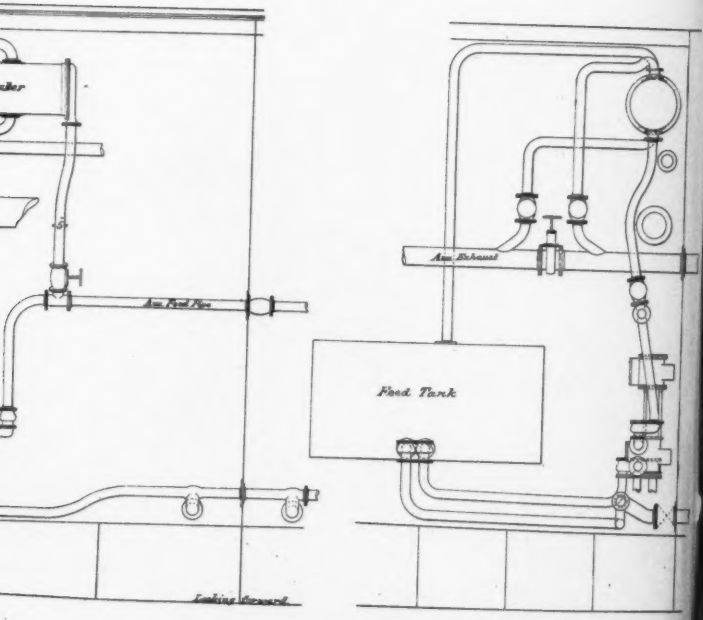


Arrangement

of

Feed Water Heater,

U. S. S. IOWA.



The sea and bilge injection valves are fitted with a self-locking arrangement so that both cannot be opened at the same time.

Diameter of steam cylinder, inches	14
Stroke, inches	12
Diameter of pump runner, inches	54½
Width of runner, inches ..... at hub, 7⅜, at rim,	3½
Diameter of inlet and outlet nozzles, inches	16

Auxiliary Condensers.—There is in each engine room a Wheeler condenser connected with the auxiliary exhaust pipes. Each has a horizontal combined air and circulating pump, the steam cylinder being between the water cylinders, and all the pistons being on one rod. The tubes are arranged and packed as in the main condensers.

Cooling surface, one condenser, square feet	800
Diameter of steam cylinder, inches	10
circulating and air pump cylinders, inches	12
Stroke, common, inches	12

Feed Water Heater.—In each engine room there is a feed water heater, which in construction, is similar to the auxiliary condensers. The auxiliary exhaust pipe has a by-pass valve, so that the steam may be passed around the tubes of the heater and thence to the condensers. The feed, fire and bilge pump takes water from the feed tank and forces it through the tubes and back to the feed tank. The heating surface is 400 square feet; the tubes are ⅝ inch in outside diameter, No. 18 B.W.G. in thickness, and are packed as in the main condensers. The general arrangement and pipe connections are shown in the cut.

Screw Propellers.—The propellers are of manganese bronze, each with three adjustable blades bent back 15 degrees. They are true screws with the pitch adjustable from 18 to 21 feet. Each boss is secured to the shaft by a feather key and a wrought steel nut screwed on and locked in place. The end of the hub is covered with a composition cap.

Number of blades	3
Diameter, feet and inches	16–6
of hub, feet and inches	4–6
Length of hub, feet and inches	3–7

Pitch as set, feet and inches	19–6
Greatest width of blade (4 feet 1½ inches from axis, feet and inches	4–10⅛
Helicoidal area of each screw, square feet	75 74
Projected area, square feet	60
Disc area, square feet	213.82
Pitch ÷ diameter	1.18
Helicoidal area ÷ disc area	.34
Projected area ÷ disc area	.28
Disc area of both screws ÷ I.M.S.	.26
Immersion of center at draught of 24 feet 0½ inch, feet and inches	15–6¼
Center above lowest point of keel, feet and inches	8–11⅝
from center line of vessel, feet and inches	13–3

BOILERS.

There are three double-ended and two single-ended steel boilers of the horizontal fire tube type, all 16.75 feet in diameter. Each double-ended boiler has eight, and each single-ended boiler, four corrugated furnaces. The shell of each double-ended boiler is made up of three courses of three plates each; the longitudinal joints are treble-riveted with double butt straps, and the circumferential joints are lapped and treble-riveted. The shell of each single-ended boiler is in one course of four plates, double butt-strapped and treble-riveted, the joints with the heads lapped and double-riveted. The joints in furnaces and combustion chambers are single-riveted. The heads of all boilers are curved at the top to a radius of 4 feet.

The furnaces are fitted with St. John's patent shaking grate bars. Each double-ended boiler has four 5-inch safety valves, two in one case, and each single-ended boiler, one 5-inch double safety valve in one case. Weir's hydrokineters are fitted to each double-ended boiler. The auxiliary feed pumps can also be used to circulate the water, pumping from the bottom blow and delivering through the auxiliary feed checks, the main and auxiliary internal feed pipes being connected and arranged to give a good distribution of the water. The tubes in all boilers are of steel.

The boilers are placed fore and aft in four water tight compartments, the two single-ended boilers occupying one compartment. There is a passage on the starboard side connecting Nos. 1 and 3 fire rooms, and another on the port side connecting Nos.

6 and 8 fire rooms. Passages amidship connect No. 3 with No. 5, and No. 4 with No. 6 fire rooms. The latter passages have water tight doors. By this arrangement, there are two athwartship fire rooms in each boiler compartment, and eight fire rooms in all. There are two circular smoke pipes. The working pressure is 160 pounds per square inch.

DOUBLE-ENDED BOILERS.

Length, feet	one of 21 and two of 19
Diameter, outside of all, feet and inches	16–9
Thickness of shell and heads at top, inches	$1\frac{37}{64}$
heads, bottom, inch	$\frac{3}{4}$
tube sheets, inch	front $\frac{7}{8}$, back $\frac{5}{8}$
furnaces, inch	$\frac{9}{16}$
Combustion chambers, number in each boiler	4
thickness of plates, inch	$\frac{9}{16}$
depth at top, inches	$27\frac{9}{16}$
Furnaces, greatest internal diameter, feet and inches	3–$8\frac{7}{8}$
least internal diameter, feet and inches	3–6
length of grate, feet and inches	6–9
number in each boiler (corrugated)	8
Tubes, outside diameter, inches	$2\frac{1}{4}$
length between tube sheets, 21-foot boiler, feet and inches	7–$7\frac{3}{8}$
19-foot boilers, feet and inches	6–$7\frac{3}{8}$
number of ordinary	948
number of stay	308
spaced vertically, inches	$3\frac{1}{4}$
horizontally, inches	$3\frac{1}{2}$
thickness of ordinary, B.W.G. No. 12, inch	.109
stay, B.W.G. No. 6, inch	.203
Diameter of rivets in shell sheets, inches	$1\frac{5}{16}$
screw stays, inches	$1\frac{3}{8}$
Number and diameter of through upper braces, inches	10 of 3
lower braces, inches	3 of 2
braces from head to back tube sheets, inches	4 of $2\frac{1}{2}$, 12 of 2, 12 of $1\frac{3}{4}$
Heating surface, tube, square feet, 19-foot boiler, 4,892; 21-foot boiler,	5,626
plate, square feet, 19-foot boiler, 936; 21-foot boiler,	936.2
total, square feet, 19-foot boiler, 5,828; 21-foot boiler,	6,562.2
Grate surface, square feet	189
Area through tubes, square feet	27.06
over bridge walls, square feet	20.62
Volume of furnaces and combustion chambers above grates, 21-foot boiler, cubic feet	744

Volume of furnaces and combustion chambers above grates, 19-foot boiler, cubic feet	724
Steam room, 4 inches above highest heating surface, 21-ft. boiler, cu. ft.	977
19-ft. boiler, cu. ft.	878.7
Water surface, 4 inches above highest heating surface, 21-ft. boiler, cu. ft.	307.5
19-ft. boiler, cu. ft.	277.5
Smoke pipes (2), diameter, feet and inches	7–9
area of both, square feet	94 34
height above lowest grates, feet	100
Number and diameter of safety valves (2 on one base), inches	4 of 5
Diameter of boiler main stop valves, inches	$10\frac{1}{2}$
auxiliary stop valves, inches	7
Totals for three boilers:	
Heating surface, tube, square feet	15,410
plate, square feet	2,808.2
total, square feet	18,218.2
Grate surface, square feet	567
Area through tubes, square feet	80.94
over bridge walls, square feet	61.86
Volume of furnaces and combustion chambers above grates, cu. ft.	2,192
steam room, cubic feet	2,734.4
Area of water surface, square feet	862.5
Ratios:	
Tube H.S. to G.S.	27.17
Plate H.S. to G.S.	4.95
Total H.S. to G.S.	32.12
Area through tubes to G.S.	.14
Volume of furnaces and combustion chambers above grates to G.S.	3.86
Steam room per square foot of G.S.	4.82

SINGLE-ENDED BOILERS.

Length, feet and inches	9–11$\frac{1}{4}$
Diameter, outside, feet and inches	16–9
Thickness of shell, inches	$1\frac{27}{32}$
heads, top, inches	$1\frac{27}{32}$
bottom, inch	$\frac{3}{4}$
tube sheets, inch	front $\frac{7}{8}$, back $\frac{5}{8}$
furnaces, inch	$\frac{9}{16}$
Cumbustion chambers, number in each boiler	2
thickness of plates, inch	$\frac{9}{16}$
depth at top, inches	$27\frac{7}{16}$
Furnaces, greatest internal diameter, feet and inches	3–8$\frac{7}{8}$
least internal diameter, feet and inches	3–6
length of grate, feet and inches	6–9
number in each boiler, corrugated	4
Tubes, outside diameter, inches	$2\frac{1}{2}$
length between tube sheets, feet and inches	6–6$\frac{1}{8}$

Tubes, number of ordinary	486
stay	152
spaced vertically, inches	3½
horizontally, inches	3½
thickness of ordinary, B.W.G. No. 12, inch	.109
stay, B.W.G. No. 6, inch	.203
Diameter of rivets in shell sheets, inches	1 5/16
screw stays, inches	1⅛
Pitch of screw stays, inches	7 and 7½
Number and diameter of through upper braces, inches	10 of 3
lower braces, inches	3 of 1¾
braces from head to back tube sheets, inches,	6 of 2, 2 of 2½, 6 of 1¾
Heating surface, tube, square feet	2,485
plate, square feet	447
total, square feet	2,932
Grate surface, square feet	94.5
Area through tubes, square feet	13.73
over bridge walls, square feet	10.31
Volume of furnaces and combustion chambers above grates, cubic feet	370
Steam room, water four inches above highest heating surface, cu. ft.	431
Water surface, water four inches above highest heating surface, sq. ft.	140
Number and diameter of safety valves (2 on one base), inches	2 of 5
Diameter of boiler stop valves, inches	7½
auxiliary stop valve, inches	7
Totals for two boilers:	
Heating surface, tube, square feet	4,970
plate, square feet	894
total, square feet	5,864
Grate surface, square feet	189
Area through tubes, square feet	27.52
over bridge walls, square feet	20.61
Volume of furnaces and combustion chambers above grates, cubic feet,	740
steam room, cubic feet	862
Area of water surface, square feet	280
Ratios:	
Tube H.S. to G.S.	26.3
Plate H.S. to G.S.	4.73
Total H.S. to G.S.	31.03
Area through tubes to G.S.	.15
Volume of furnaces and combustion chambers above grates to G.S.	3.91
Steam room per square foot of G.S.	4.56

ALL BOILERS.

Heating surface, tube, square feet	20,380
plate, square feet	3,702.2

Heating surface, total, square feet	24,082.2
Grate surface, square feet	756
Area through tubes, square feet	108.46
over bridge walls, square feet	82.47
Volume of furnaces and combustion chambers above grates, cubic feet,	2,932
steam room, cubic feet	3,596.4
Area of water surface, square feet	1,142.5
Ratios:	
Tube H.S. to G.S.	26.96
Plate H.S. to G.S.	4.89
Total H.S. to G.S.	31.85
Area through tubes to G.S.	.143
Volume of furnaces and combustion chambers above grates to G.S.	3.88
Steam room per square foot of G.S.	4.76

Forced Draft.—The closed fire room system of forced draft is used. The air is supplied by eight Sturtevant blowers, one in each fire room. The fans are driven by two-cylinder, vertical, simple, enclosed engines with cranks at 180 degrees.

Diameter of steam cylinders, inches	5
Stroke, inches	4
Diameter of fan, inches	60
Width of fan at rim, inches	14
Area of induction nozzle, square inches	1,060.7
Area of eduction nozzle, square inches	1,920

Feed Pumps.—There are two main and three auxiliary feed pumps, located as follows: No. 1 fire room, one auxiliary; No. 3 fire room, one auxiliary; No. 4 fire room, one main; No. 5 fire room, one auxiliary, and No. 6 fire room, one main pump.

	Fire room No 1.	No. 3.	Nos. 4 and 6.	No. 5.
Diameter steam cylinders, inches	6	10	12	12
water cylinders, inches	4	5¾	7¾	7
Stroke, inches	7	12	12	12
Capacity, gallons per minute	90	260	350	350

The main feed pumps take water from the air pump suctions and feed tanks and deliver it to boilers; the auxiliary feed pumps draw from the air pump suctions, feed tanks, sea, boilers, bilges, cisterns and secondary drain pipe, and deliver it to boilers, fire main and overboard. The discharges of the main and auxiliary pumps are not connected, but all of them can feed any boiler.

Feed, Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double-acting Blake pump which draws from the sea, the bilge, the secondary drain pipe, the drainage cistern, the feed tanks and the air pump suctions, and delivers into the main and auxiliary feed pipes, the fire main, overboard and feed water heater. The steam cylinders are 12, and the water cylinders, 7 inches in diameter; stroke, 12 inches. The capacity of each pump is 350 gallons per minute.

Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double-acting Blake pump which draws from the sea, the bilge, the secondary drain pipe and the drainage cistern, and delivers into the fire main and overboard. The steam cylinders are 12, and the water cylinders, 7 inches in diameter; stroke, 12 inches. The capacity of each pump is 350 gallons per minute.

Water Service Pumps.—In each engine room there is a vertical, duplex, double-acting Blake pump which draws from the sea, and delivers into the water service pipes and fire main. The steam cylinders are 8, and the water cylinders, 5 inches in diameter; stroke, 12 inches. The capacity of each pump is 200 gallons per minute.

Ash Hoists.—In each main fire room hatch there is a Williamson Bros.' double, reversible ash hoist, by means of which one bucket of ashes of 300 pounds (with a steam pressure of 60 pounds) can be hoisted in 5 seconds. The steam cylinders are $4\frac{1}{2}$ inches in diameter, with a piston stroke of $4\frac{1}{2}$ inches.

Grease Extractors.—There is a grease extractor on the discharges of both main feed pumps. It is similar to a Macomb strainer; the basket is perforated and covered with burlap through which the water filters. By-pass pipes and valves are fitted to feed the boilers while overhauling the extractor.

Feed Tanks.—There is a feed tank of 2,000 gallons capacity in each engine room. A part of the tank is fitted as a filter into which the water from the air pumps is delivered. The filter is provided with sponges, which are readily accessible. Each tank has a man hole, glass water gauge, shut-off and drain cocks. An overflow pipe is fitted and so arranged that any water passing down it may be seen. Each feed pump suction is provided with

a balance valve, operated by a copper float in the feed tank and so arranged that no air will enter the feed pipes.

Steam Traps.—The separators, the jackets, the main and auxiliary steam pipes, the radiators, and all places where condensed steam can accumulate are fitted with drain pipes and cocks, or valves, and with automatic traps which discharge into the feed tanks. The traps are provided with by-pass pipes and valves for convenience of overhauling.

Workshop.—The workshop is situated on the berth deck and is the largest of any ship in the Navy. It is fitted with a vertical engine, 8 inches by 8 inches, 2 lathes, a shaping machine, a double-geared drilling machine, a small bench drilling machine for hand or power, combined punch and shears and an emery tool grinder.

Distilling Apparatus.—There are two Baird distillers and two evaporators with a maximum distilling capacity of 7,500 gallons of potable water in twenty-four hours. A Davidson compound pump (steam cylinders, 6 and 12, and water cylinders, 9 inches in diameter, stroke, 12 inches), is used to circulate the water through the distillers. After leaving the distillers, the circulating water passes through the flushing pipes, and by-pass valves and pipes are fitted so that the water can enter the flushing pipes without passing through the distillers. A Davidson horizontal combined pump is used for a brine pump, and to deliver the water from the filters to the ship's tanks; it has a steam cylinder 4 inches, and water cylinders $2\frac{3}{8}$ inches in diameter, and a stroke of 5 inches. There is a duplex pump to deliver the drain water from the evaporators into the feed tank; the steam cylinder is 2, and the water cylinder, $1\frac{1}{4}$ inches in diameter, and the stroke, $2\frac{3}{4}$ inches. There is also a pump for feeding the evaporator; steam cylinder, $4\frac{1}{2}$, and water cylinder, $2\frac{3}{4}$ inches in diameter, stroke, 6 inches.

Ventilating Fans.—There is in each engine room a ventilating fan which is used only for engine room service. For ventilating the ship generally, there are six fans situated on the berth and orlop decks, arranged, by means of reversible valves, to exhaust from, or force air to the various parts of the ship. The fans are driven by engines similar to those of the forced draft blowers.

Diameter of steam cylinders (2), inches	4
Stroke, inches	3
Diameter of fan, inches	48
Width of fan, inches	19

Vedette Steam Launch.—This launch is 40 feet long, and has a triple expansion engine and a keel condenser. The cylinders are $4\frac{1}{2}$, $7\frac{1}{4}$ and $11\frac{1}{2}$ inches in diameter, the stroke being 8 inches. It has one Ward boiler, type G-1, with a grate surface of 9.37, and a heating surface of 207 square feet.

Steam Cutters.—There are two steam cutters, one 33 and the other 30 feet long. They have Ward boilers, type D Square, compound engines and keel condensers. The cylinders for the 33-foot cutter are 4 and 8 inches in diameter by 6 inches stroke, and those for the 30-foot cutter, $3\frac{1}{2}$ and 7 inches in diameter by 6 inches stroke.

Telegraphs and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in conning tower, pilot house and bridge, and a mechanical gong in each engine room with bell pulls at the steering wheels at after part of the superstructure deck. Mechanical tell-tales are fitted on the bridge and in the conning tower to show the direction of revolution of the main engines. In each engine room there is a mechanical indicator to show the relative speed and direction of revolution of the propellers on one dial.

Telephones and Voice Pipes.—For communication between the various parts of the ship there is a complete system of telephones, and voice pipes with call bells. The most important stations are connected direct with voice pipes, but for general purposes, a central station is used.

Steering Engine.—On the after platform deck there is a Williamson Bros.' combined hand and steam steering engine; cylinders, 13 inches in diameter; stroke, 10 inches. The engine is connected to a horizontal fore-and-aft shaft, on the after end of which is a right-and-left-hand screw. The screw works in two crossheads, one on the starboard and one on the port side, the rudder yoke being connected by rods to these crossheads. With the steam gear, the rudder can be put hard over from amidships in 10 seconds when the ship is going full speed.

Steam Windlass.—On the main deck forward there is a steam windlass. The engine is reversible, double cylinder, vertical, direct-acting, with cylinders 15 inches in diameter, and a stroke of 14 inches. The windlass is fitted with four wild cats to take the chains and two drums to take hawsers.

Winches.—There are four Williamson Bros.' double cylinder winches situated as follows:—Two forward of the 12-inch forward turret on the upper deck, one amidships on the upper deck and one abaft the after 12-inch turret on the main deck. Those forward and abaft the turrets have cylinders 8 inches in diameter and a stroke of 8 inches. The amidship winch has cylinders 6 inches in diameter and a stroke of 8 inches.

On each side amidships is a boat crane, with double cylinder Williamson engines, 10 inches in diameter and 8 inches stroke. The engines are attached to the cranes, each of these having one large and two small drums and an arrangement for revolving the crane.

Twelve-inch Turret Turning Gear.—For each turret there are two three-cylinder, single-acting water motors. The connecting rods are attached to the pistons and all three work the same crank. The motors are fixed to the floor of the turret, and a pinion on the crank shaft engages a circular rack fast to the ship's structure, the motors revolving with the turret.

The motors are operated by a change valve worked by a hydraulic cylinder, the piston rod of which is a prolongation of the change valve stem. The valve of the hydraulic cylinder is worked by a hand wheel, the threaded spindle of which works through a nut which receives motion by gearing from the turret rack. The hand wheel spindle is attached to the end of a floating lever to which are also attached the valve stem and piston rod of the hydraulic cylinder. It is a combination of the Williamson with the Cramp reverse gear. The hand wheel is horizontal, and the turret follows its motion and stops when it is stopped.

The motor cylinders are $8\frac{1}{2}$ inches in diameter, the stroke being 8 inches. The guns are worked by hand, and are loaded by means of sectional rammers worked by electric motors.

Eight-inch Turret Turning Machinery.—Each 8-inch turret is turned by a double, vertical engine, with cylinders 8 inches in diameter and 7 inches stroke, located in the ammunition passages on the orlop deck. A gear wheel on the crank shaft of the engine, through an intermediate train, causes two worms to revolve a worm wheel on the friction gear on the lower end of the ammunition tube. Each engine is provided with a controlling valve, which can be operated at the engine, and also from the sighting hoods of the turrets by means of shafting and gearing. Automatic stop gear is provided to prevent the turrets from turning too far. In case the engine becomes disabled, provision is made for turning by hand.

Hydraulic Plants.—There are two hydraulic plants situated forward of the forward fire rooms in the hold. They are used to work the 12-inch turrets and to hoist the ammunition for the guns in them. Each plant consists of one vertical, double-acting duplex Worthington pump, an accumulator, water tank and the necessary piping. The combined capacity of the pumps is 1,500 gallons per minute, the working pressure being 600 pounds per square inch. This duty is done with 100 pounds steam pressure at the pump throttles. The accumulator consists of a steam cylinder, a steam piston and a water plunger. The quantity of steam furnished the pumps is governed by the height of the steam piston in its cylinder; the steam for the pumps passes through a tail pipe bolted to the piston and pierced with holes which will be shut off as the piston rises. A vertical tube, closed at the top and with a connection to the valve chests of the pumps, forms a casing for the tail pipe.

The water tank has a capacity of 200 gallons, and fresh water only is used.

The delivery pipes are $4\frac{1}{2}$ inches in diameter and of seamless drawn brass; the return pipes are 5 inches in diameter and of copper. The flanges of the pressure pipes are of the Folly patent type. The delivery and return pipes lead to a double composition pipe casting around which a composition chamber revolves. The revolving chamber turns with the turret; it is divided into pressure and exhaust passages, and the joints are made with cup-leather packing. The delivery and return pipes from the cylin-

ders, for working the turret and hoisting the ammunition, are connected to the revolving chamber. All parts of the hydraulic system, except the suction, were tested to 1,200 pounds water pressure.

Steam cylinders, number	4
diameter, inches	29
stroke, inches	18
Water plungers, number	4
diameter, inches	10
stroke, inches	18
Accumulator, steam cylinder, diameter, inches	25
water plunger, diameter, inches	10
stroke, inches	36

Electric Plant.—The installation consists in general of four generating sets, 500 incandescent lights, 4 search lights, 1 set of signalling apparatus, 2 stationary ventilating fans driven by electric motors, 4 portable ventilating fans driven by electric motors, electric motors for the ammunition hoists, 1 main switch board, together with the necessary wire, wiring accessories, molding and fixtures.

The four generating sets were made by the General Electric Company. In each set there is a 24-kilo-watt dynamo of the multipolar type, having a capacity of 300 amperes at 80 volts, compound-wound on 144 armature sections cross-connected at 180 degrees. The engines driving the dynamos are two-cylinder, vertical, inverted; diameter of cylinder, 10½ inches; stroke, 5 inches. The crank and armature shafts are connected by a rigid coupling. The engines are designed to run, with full load, at 400 revolutions per minute with 80 pounds steam pressure. The bed plate is common to both engine and dynamo and measures 7 feet 3 inches by 3 feet 10 inches. The weight of each generating set (engine, dynamo and bed plate) is about 8,500 pounds. The incandescent lights are of 16 and 32-candle power designed for 80 volts.

There are four search lights, of about 25,000-candle power each, made by the General Electric Company; two mounted on the top of the forward bridge, and two, on the after bridge. The projectors are 75 centimeters in diameter and electrically controlled. All lamps are horizontal combination, hand or auto-

matic, and designed for a current of 100 ampers at about 50 volts. The carbon holders are adjustable, and the life of the carbon is six hours.

The signal apparatus is of the usual Ardois type, and consists of four double signal lanterns, cable connection and key board.

There are two stationary ventilating fans, one arranged to force air into, and the other to exhaust the air from the dynamo room. Each fan is capable of delivering 2,200 cubic feet of air per minute at a speed of 1,570 revolutions, and is connected directly to a 2-horse power electric shunt motor.

There are four portable fans, to be used to exhaust the air from the double bottoms and various compartments. Each fan is capable of delivering 400 cubic feet of air per minute at a speed of 1,863 revolutions, and is directly connected to a ¼-horse power electric series motor.

There is a standard Navy switchboard complete, containing the necessary connections, switches, cut-outs, &c., for 11 incandescent, 4 search light and 11 motor circuits. It is provided with a pressure board, ground detector and measuring instruments.

The pressure board has points connecting the volt meter with the terminals of each of the dynamos, and with each of the search light circuits. The ground detector is arranged to be thrown on either arc or incandescent circuit when operated separately.

Electric speed indicators and transmitters are fitted on the bridge, pilot house and in conning tower; also electric helm indicators.

There are thermostats in each coal bunker, and in certain store rooms, with an annunciator on bulkhead forward of cabin.

There are eight 7-horse power electric motors for hoisting ammunition, in the 8-inch turrets, and seven other electric ammunition hoist motors in various parts of the ship, of about 5-horse power each.

Ice Machine.—There is an Allen dense air machine capable of making one ton of ice per day, or 200 pounds of ice and at the same time keeping the refrigerating rooms near the freezing point, and cooling 300 gallons of water to 40 degrees Fahrenheit. Steam cylinder, 7, air compressor cylinder, 5¾, and air expansion cylinder, 4¾ inches in diameter; stroke, 10 inches.

The circulating water and primer pumps are single-acting, each 1⅝ inches in diameter and 10 inches stroke.

NUMBER OF ENGINES ON *IOWA*.

Engines.		*Steam cylinders.*
2	main propelling engines,	6
2	main air pumps,	4
2	main circulating pumps,	2
2	auxiliary air and circulating pumps,	2
2	main reversing engines,	2
2	main turning engines,	4
1	workshop engine,	1
4	evaporator and distiller pumps,	4
1	oil pump,	2
2	feed, fire and bilge pumps,	4
2	fire and bilge pumps,	4
2	water service pumps,	4
2	main feed pumps for boilers,	4
1	auxiliary feed pump for boilers,	2
2	auxiliary feed pumps for boilers,	4
8	forced draft blowers,	16
2	ventilating blowers in engine room,	4
6	ventilating blowers for ship,	12
8	ash hoisting engines,	16
4	dynamo engines,	8
1	steering engine,	2
1	light service pump, hydraulic room,	1
4	8-inch turret turning engines,	8
1	ice machine,	1
1	windlass and capstan engine,	2
4	winches,	8
2	boat crane engines	4
2	hydraulic pumps,	4
1	accumulator,	1
4	steam turbines for torpedo tubes,	4
1	pump for waste water tank,	1
3	steam cutter propelling engines,	7
4	steam cutter feed pumps,	4
86	Total,	152

OFFICIAL SPEED TRIAL.

The official speed trial took place off the New England coast on Wednesday, April 7, 1897. It consisted of two runs over a measured course of 33 nautical miles. The time occupied in making the first run, (to the northward), was 1 hour 57 minutes 21 seconds, and the return run, 1 hour 55 minutes 36 seconds. Total time in making the two runs, 3 hours 52 minutes 57 seconds. Tidal corrections applied to the trial course made the distance through the water 66.3407 nautical miles, and the true mean speed, 17.0871 knots. The weather was fine; long, slight swell on starboard quarter while going north; wind light, force of 3 on the Beaufort scale. All boilers were in use under forced draft, all fire rooms being connected. All the steam generated was used by the main engines and auxiliaries, except that used in the steering engine and in the engine for the dynamo to light the engine and boiler compartments. The coal used was hand-picked Pocahontas. The boilers steamed freely and steadily, and showed no evidence of priming. The main engines worked very regularly and without vibration. A very small stream of water was kept on the S.I.P. and S.L.P. eccentrics, and on the S.I.P. main journals, as a precautionary measure during the second run. The air and circulating pumps and other auxiliaries worked well. Between the end of the first and beginning of the second run, while the helm was put over, no noticeable effect was produced on the revolutions of either main engine.

After the trial the boilers, main engines and auxiliaries were examined and found in good condition.

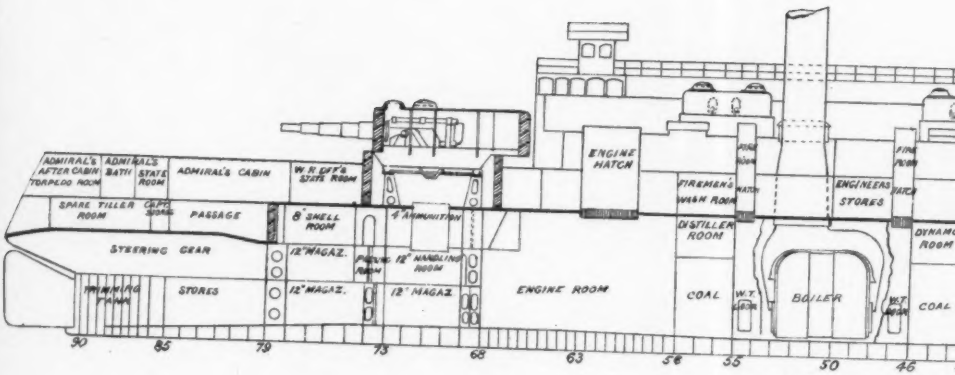
DATA OF OFFICIAL TRIAL.

Draught, mean for trial, forward, feet and inches	23–8¾
aft, feet and inches	24–4¼
average, feet and inches	24–0½
Displacement at mean draught on trial, tons	11,363
Area of immersed midship section, square feet	1,635
Wetted surface, square feet	31,110
I.H.P. (total) per 100 square feet of wetted surface	38.9
at 10 knots, reduced in ratio of 3.5 power,	5.97
Average speed in knots	17.0871

Slip (mean of both screws), per cent	20.93
Speed^3 × area of immersed midship section ÷ I.H.P.	673.84
displacement$^{\frac{2}{3}}$ ÷ I.H.P.	208.30

SYNOPSIS OF STEAM LOG.

	Starboard.	*Port.*
Revolutions of main engines per minute, mean	108.61	110.51
Piston speed in feet, per minute	868.88	884.08
Steam pressure at boilers, per gauge	161	
engines, per gauge	156.7	153.6
1st receiver, absolute	78.6	76.7
2d receiver, absolute	27.5	27.15
Vacuum in condensers, inches of mercury	24.1	
Opening of throttle	wide.	
Steam cut off in fractions of stroke from beginning, H.P.	.67	
I.P. and L.P.	.72	
Double strokes of air pump, per minute	24.	23.6
Revolutions of circulating pumps per minute	131.7	110.3
Temperatures in degrees, Fahrenheit, engine room	87	90
injection	57	57
discharge	132	123
hot well	129	123
feed	134	154
fire rooms	108	
Air pressure, in inches of water, in fire rooms	.987	
Revolutions of blowers per minute, fire rooms	471	
engine rooms	405	
Mean pressures in cylinders, H.P.	55.70	51.57
I.P.	34.53	33.46
L.P.	14.07	14.26
equivalent reduced to L.P.	39.77	38.67
I.H.P.:		
H.P. cylinder	1,716.98	1,617.3
I.P. cylinder	2,138.30	2,108.7
L.P. cylinder	2,093.90	2,159.3
Collective, each main engine	5,949 18	5,885.3
both main engines	11,834.48	
Air pumps	8.36	8.34
Circulating pumps	9.73	7.22
Feed pumps (4)	65	
Blowers, forced draft (8)	104 6	
Other auxiliaries	67.07	
Collective, all auxiliaries	236.67	
main engines, air and circulating pumps (A)	11,868.13	
total, all machinery in operation	12,104.8	
Indicated thrust (main engines only), pounds	92,698	90,125



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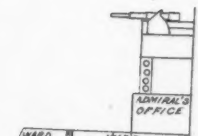

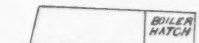

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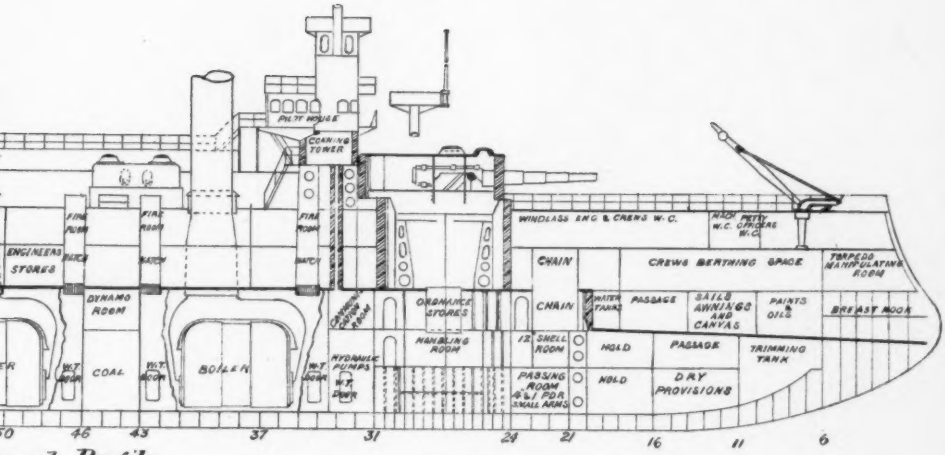

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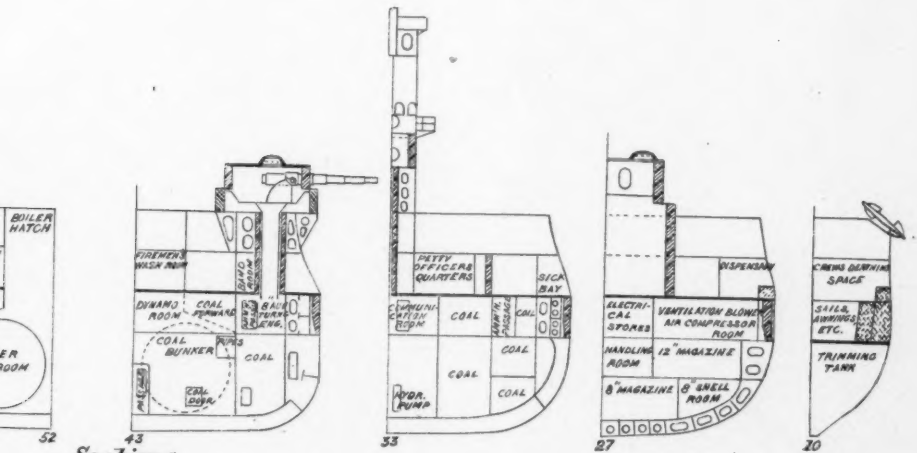
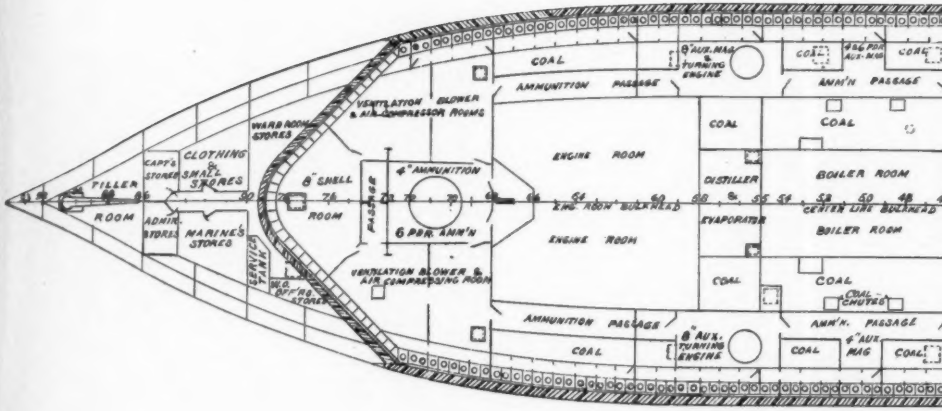


Sections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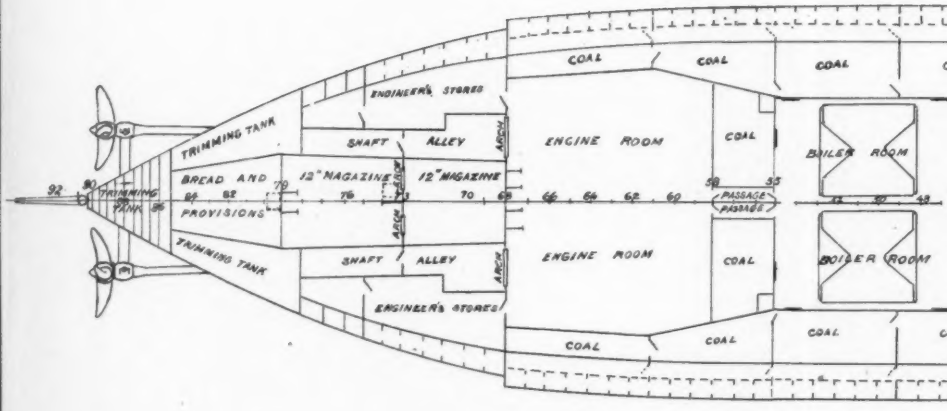
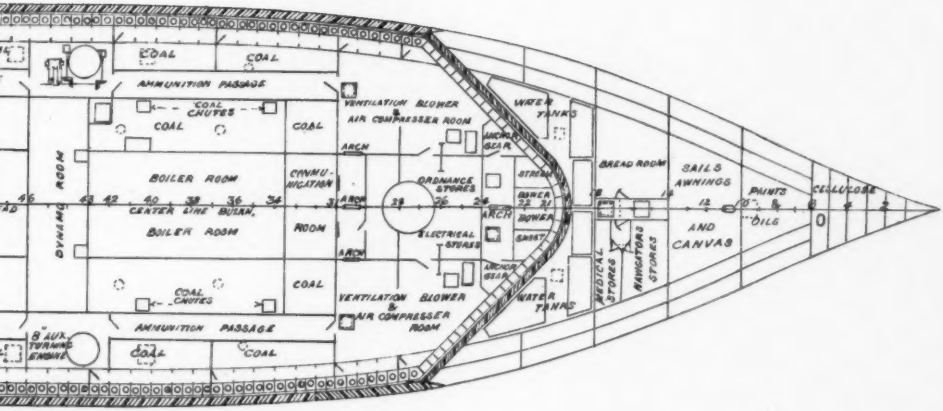
AMMUNITION PASSAGE
9" AUX. MAG & TURNING ENGINE
ANM'N PASSAGE
VENTILATION BLOWER & AIR COMPRESSOR ROOMS
WARD ROOM STORES
CAPT'S STORES
CLOTHING & SMALL STORES
TILLER ROOM
ADM'TY STORES
MARINES STORES
SERVICE TANK
8" SHELL ROOM
4" AMMUNITION PASSAGE
6 PDR. ANM'N
ENGINE ROOM
ENG. ROOM BULKHEAD
DISTILLER & EVAPORATOR
BOILER ROOM
CENTER LINE BULKHEAD
COAL CHUTES
8" AUX. TURNING ENGINE
4" AUX. MAG

Protective


ENGINEER'S STORES
TRIMMING TANK
SHAFT ALLEY
ARCH
ENGINE ROOM
COAL
BOILER ROOM
BREAD AND PROVISIONS
12" MAGAZINE
PASSAGE
ENGINEER'S STORES



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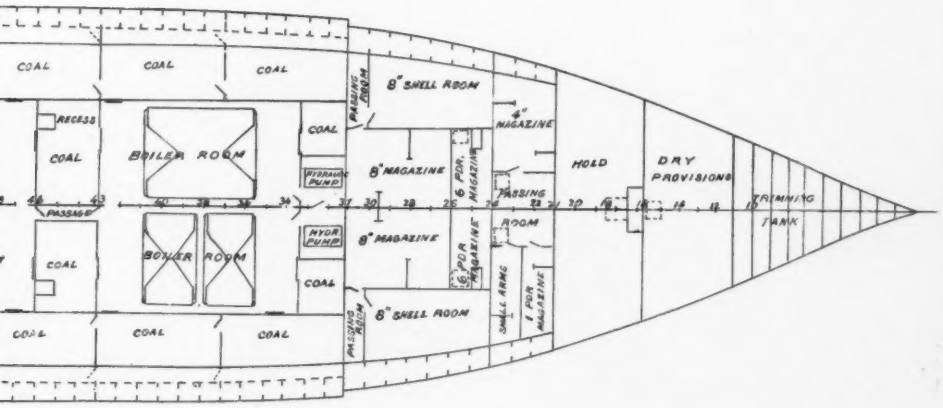

Hold

Indicated thrust per square foot of developed area of propellers, pounds	1,189.9	1,223.9
per square inch of thrust bearing, pounds	36.68	35.66
Cubic feet swept per minute by L.P. piston, per I.H.P. (A)	5.71	5.88
Ratio of volume swept by one L.P. piston to that of the two buckets of one air pump, per minute	70.36	72.81
Square feet of cooling surface per I.H.P. (A)	1.36	
total heating surface per total I.H.P	1.99	
I.H.P per square foot of G.S. (all machinery in operation)	16.01	
H.S. (all machinery in operation)	.503	

ON CRANK SHAFTS.

By J. H. Macalpine, Esq., Associate Member.

[Continued from page 359, Volume IX.]

Appendix B.

On the distribution of shearing stress in an isotropic circular beam.

This appendix contains another application of Saint-Venant's solution of the problem presented by the equilibrium of a beam under stress.

Suppose the beam fixed at one end and bent by a transverse force applied at the free end. As in Appendix A, the solution involves the condition that there are no normal tractions across longitudinal planes. Only if the distribution of the applied forces over the free end is that given by equations (34) and (35) below, will this condition be fulfilled exactly; then the same distribution of shearing stress will hold at all cross-sections of the beam. In practice we can never expect to have the external force distributed in this fashion; but still the condition may be supposed to hold except very near the parts subjected to these surface tractions [§ 106]—even there, with sufficient accuracy, if the external forces are not applied too locally.

Internal stresses due to processes of manufacture are not contemplated when treating any such problem. The stresses induced by the applied forces add themselves to those already in the material, and the presence of the latter indefinitely reduces the intensity of the applied force system at which the elastic limit may be reached. This is one of the many reasons for the use of a comparatively large factor of safety; it also, probably, accounts for the occurrence of small sets in many bars under test,

long before that rather indefinite strain called the elastic limit, is attained.

In Figs. XXVIII and XXIX, the axis of z is taken along the axis of the beam; and the axes Ox, Oy lie in the section. The origin O is taken at the center of the fixed end of the beam.

The point (x, y, z), of the unstrained beam, is displaced to $(x + u, y + v, z + w)$; that is, u, v, w, are the displacements parallel to the axes of x, y and z, respectively.

Let l be the length of the beam.

S, T, U and μ are as defined in Appendix A.

E is Young's modulus for the material. For steel it may be taken as 30×10^6 pounds per square inch.

σ is the ratio of lateral contraction to longitudinal extension (Poisson's ratio)—got by dividing the lateral strain (contraction per unit length) by the longitudinal strain (extension per unit length) experienced by the bar when subjected to a simple longitudinal pull.

$E/\mu = 2\,(1 + \sigma)$ [III, 9 and 10; eliminate λ]. *

$E = 30 \times 10^6$ and $\mu = 12 \times 10^6$ gives $\sigma = .25$, the value frequently taken. This value seems to be fairly accurate for steel where isotropic, and for wrought iron, though experiment indicates that σ has a considerable range for different materials and, as we might perhaps expect, for the same material where the treatment has been different [§§ 28, 30 and 45]. It would be rash to assume that the steel in a crank shaft is always nearly isotropic. The variation in the quality of metal in various parts of the same bar or ingot is a fact always kept in mind by every practical engineer. But there seems to have been little or no discussion of the values of σ for materials as actually employed in engineering. Indeed, the values to be assigned to this quantity is one of the principal questions in dispute between the two schools into which elasticians are divided. Hence the adoption here of $\sigma = .25$ is only to be looked on as provisional and for the sake of definite illustration. The exact determination of this quantity is of great practical importance; but a comparatively large change in its value affects the curves in this appendix but

* See also Appendix F.

little. This was verified by recalculating the most important stresses for the various values of r_2/r_1, taking $\sigma = .4$. This value probably lies far outside that occurring in steel and undrawn brass; that is, for most practical cases the curves may be accepted as sensibly accurate. The following high values are, however, given by Mr. Love [§ 30]:—

Brass (drawn), $\sigma = .468$. *Authority*, Everett.
Copper, $\sigma = .378$. *Authority*, Everett.
Lead, $\sigma = .428$. *Authority*, Amagat.

The values for drawn brass and copper are deduced by calculation from the observed values of other elastic constants.

Let r_1 and r_2 be the outer and inner radii of the bar.

Let X be the total applied transverse force, its resultant being parallel to Ox.

$$u = \frac{2X}{E\pi(r_1^4 - r_2^4)} \left\{ \sigma(l-z)(x^2 - y^2) + z^2\left(l - \frac{1}{3}z\right) \right\} \cdot$$

$$v = \frac{4X}{E\pi(r_1^4 - r_2^4)} \sigma(l-z)\, xy. \qquad \Bigg\} \ldots$$

. . . [VI, first two equations of 119. These are for a solid beam. For a hollow beam a^4 must be changed to $a^4 - b^4$ (Mr. Love's notation) or $r_1^4 - r_2^4$ (notation of present paper). See first two equations of VI, 105, which are more general. $\sigma_1 = \sigma_2 = \sigma$.]

$$w = \frac{2X}{E\pi(r_1^4 - r_2^4)} \left\{ (z^2 - 2lz)\, x - \left(\frac{E}{\mu} - 2\sigma\right) xy^2 \right.$$

$$\left. + \left(\frac{3}{4}\frac{E}{\mu} - \frac{1}{2}\sigma\right) \frac{(r_1^2 + r_2^2)(x^2 + y^2) + r_1^2 r_2^2}{x^2 + y^2} x + \left(\frac{1}{2}\sigma - \frac{1}{4}\frac{E}{\mu}\right)(x^3 - 3xy^2) \right\} \cdot$$

. . . [VI, 124; $\sigma_1 = \sigma_2 = \sigma$.]

Putting $\sigma = \frac{1}{2}\lambda/(\lambda + \mu)$, ... [III, 10]

we have,

$$P = \lambda\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) + 2\mu\frac{\partial u}{\partial x},$$

the expressions for Q and R being obtained by cyclical interchange of the coordinates x, y, z and also of the displacements u, v, w;

$$S = \mu\left(\frac{\partial w}{\partial y} + \frac{\partial v}{\partial z}\right),$$

the expressions for T and U being obtained by the same interchanges. . . . [III, 11]

Using the above values of u, v and w, we find

$$P = Q = U = 0 \text{ as supposed.}$$

$$R = -\frac{4X(l-z)x}{\pi(r_1^4 - r_2^4)}.$$

Thus the tensions and compressions parallel to the axis of the beam are the same as are given by the usual imperfect theory of crossbending.

$$S = -\frac{4X\mu xy}{E\pi(r_1^4 - r_2^4)}\left[\frac{1}{2}\sigma + \frac{1}{4}\frac{E}{\mu} + \left(\frac{3}{4}\frac{E}{\mu} - \frac{1}{2}\sigma\right)\frac{r_1^2 r_2^2}{(x^2+y^2)^2}\right]. \quad (34)$$

$$T = \mu\left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}\right)$$

$$= \frac{2X\mu}{E\pi(r_1^4 - r_2^4)}\left[\left(\frac{1}{2}\sigma - \frac{3}{4}\frac{E}{\mu}\right)\left\{(x^2 - y^2)\left(1 + \frac{r_1^2 r_2^2}{(x^2+y^2)^2}\right) - (r_1^2 + r_2^2)\right\} - y^2\left(\frac{E}{\mu} - 2\sigma\right)\right]. \quad (35)$$

Putting $x^2 + y^2 = r_1^2$, or $= r_2^2$, in equations (34) and (35), gives

$$S : T :: x : y,$$

which shows that the resultant shearing stress is tangential at all points of the boundary. That this condition must always hold can at once be seen by referring to Fig. I. We have there the shearing stresses U applied to the faces AB and CD, of thickness τ, composing a couple which is equilibrated by the equal and opposite couple arising from the shearing stresses U applied

to the faces AD and BC. But if AB is a portion of the face of the solid of which we may suppose $ABCD$ to be an infinitesimal parallelepiped, the shearing stress U applied to AB cannot exist (surface tractions not being considered). Hence the parallelepiped will take up such a position that the equilibrating couple applied to faces AD and BC will vanish also; or, the shearing stress normal to the boundary must always be zero. From this it readily follows that the shearing stress at a projecting angle must always be zero.

Putting $E = 30 \times 10^6$, $\mu = 12 \times 10^6$ and $\sigma = .25$, in equations (34) and (35), we get,

$$S = -\frac{.3820\, X xy}{r_1^4 - r_2^4}\left\{1 + \frac{2.333\, r_1^2 r_2^2}{(x^2+y^2)^2}\right\}, \quad \ldots \ldots \ldots \quad (36)$$

$$T = \frac{.5093\, X}{r_1^4 - r_2^4}\Big[.875\left\{(r_1^2 + r_2^2) - (x^2 - y^2)\left(1 + \frac{r_1^2 r_2^2}{(x^2+y^2)^2}\right)\right\} - y^2\Big]. \quad \ldots \quad (37)$$

To get the shearing stress round the outer circumference of the beam we must put for x and y, in equations (36) and (37), $x = r_1 \cos \xi$ and $y = r_1 \sin \xi$.

ξ is the angle between the radius to the point at which the stress is measured, and Ox.

Then,

$$S = -\frac{.1910\, X \sin 2\xi}{r_1^4 - r_2^4}(r_1^2 + 2.333\, r_2^2).$$

$$T = \frac{.3820\, X \sin^2 \xi}{r_1^4 - r_2^4}(r_1^2 + 2.333\, r_2^2).$$

These give for the total shearing stress,

$$\sqrt{(S^2 + T^2)} = \frac{.3820\, X}{r_1^4 - r_2^4}(r_1^2 + 2.333\, r_2^2) \sin \xi. \quad \ldots \quad (38)$$

Similarly the shearing stress round the inner circumference is

$$\sqrt{(S^2 + T^2)} = \frac{.3820\, X}{r_1^4 - r_2^4}(2.333\, r_1^2 + r_2^2) \sin \xi. \quad \ldots \quad (39)$$

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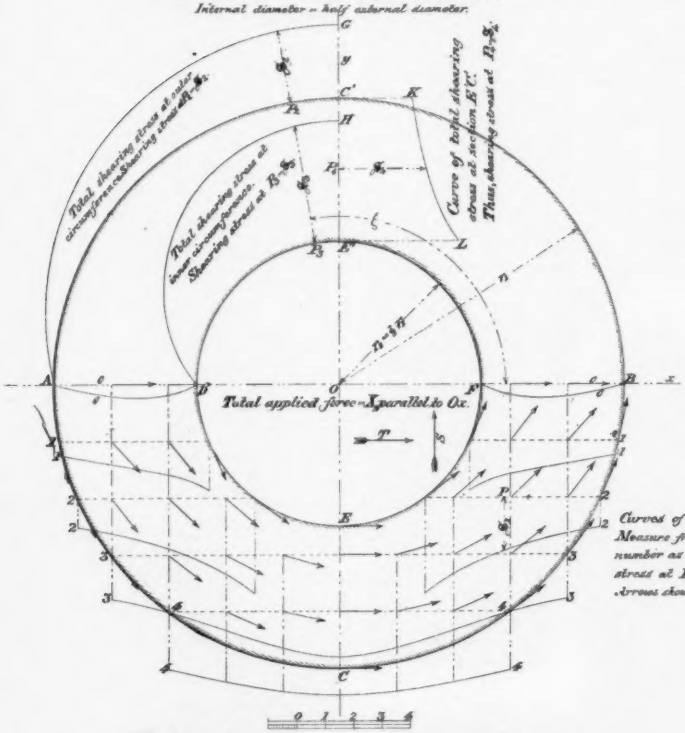
Fig XXVIII.

Curves of Shearing Stress in an Isotropic Circular Beam Strained by Transverse Force.

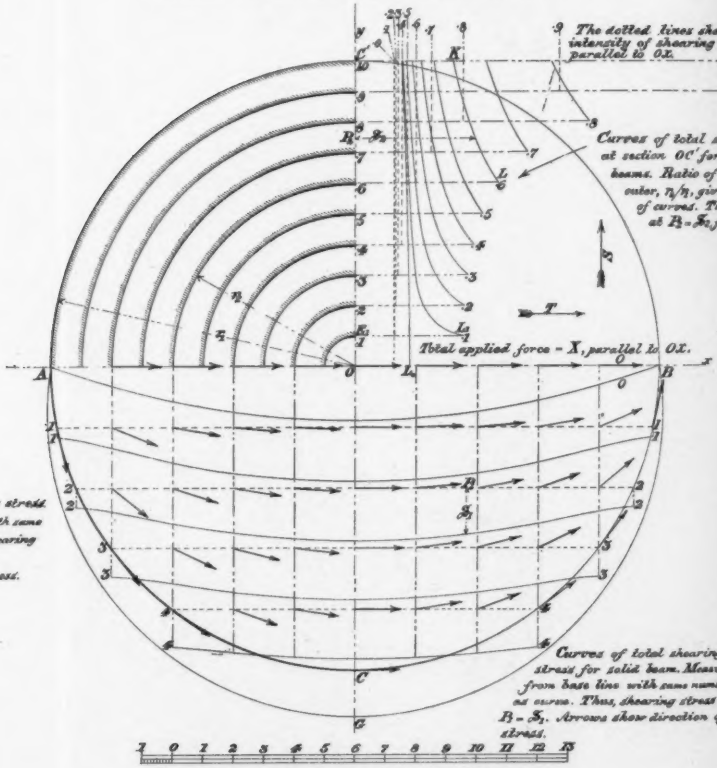
Internal diameter = half external diameter.



The Scale gives shearing stress (unaugmented) in pounds per square inch for X = one pound, the outside diameter of the beam being one inch.

Fig. XXIX.

Curves of Shearing Stress in an Isotropic Circular Beam Strained by Transverse Force.


The dotted lines show the mean intensity of shearing stress parallel to OX.
Curves of total shearing stress at section OC' for solid and hollow beams. Ratio of inner radius to outer, r/r1, given at lower ends of curves. Thus, shearing stress at B1 = S1 for r/r1 = ·6.
Total applied force = X, parallel to OX.
Curves of total shearing stress for solid beam. Measure from base line with same number as curve. Thus, shearing stress at B1 = S1. Arrows show direction of stress.
The scale gives shearing stress (unaugmented) in pounds per square inch for X = one pound, the outside diameter of the beam being one inch.

The results shown in Figs. XXVIII and XXIX are calculated from equations (36) to (39).

In Fig. XXVIII, $r_2/r_1 = .5$. $ACBC'$ is the outer circumference of the section of the bar and $DEFE'$ the inner circumference. The axis of x is taken along AB.

The total shearing stresses—$\sqrt{S^2 + T^2}$, equations (36) and (37)—at various surface and internal points are shown by the curves in the lower half of the figure. These curves are on bases parallel to AB, numbered 0, 1, 2, 3, 4. The curves and bases with the same numbers correspond—thus, the stress at P_1, base line 2, $= \mathbf{S}_1$ as shown. An arrow shows the direction of stress at the point from which it is drawn, the angle being determined by the ratio S/T.

The curves AG and DH show the stress round the outer and inner circumferences—thus, the stress at $P_2 = \mathbf{S}_2$ and the stress at $P_3 = \mathbf{S}_3$. As these stresses are proportional to $\sin \xi$—equations (38) and (39)—the shearing stresses round the outer and inner circumferences are completely known when the values at C' and E' have been calculated.

The curve KL gives the shearing stresses at the points of the section $E'C'$ obtained from equation (37) by putting $x = 0$. Thus the shearing stress is highest at the point E' where the axis of y meets the internal surface. This is always the case in a hollow circular beam whatever the ratio r_2/r_1 is.

The scale gives unaugmented shearing stresses in pounds per square inch for $X =$ one pound and the outside diameter of the shaft = one inch. In respect to these stresses the strength of any shaft, circular or otherwise, is proportional to the second power of the linear dimensions.

The lower half of Fig. XXIX shows the shearing stresses for a solid beam. As it is lettered correspondingly to Fig. XXVIII, it requires no further explanation.

The full line curves, such as KL, in the upper half of Fig. XXIX, give by their x ordinates the shearing stress at the section Oy for a series of shafts in which the ratio r_2/r_1 has the values 0, .1, .2, . . . , .9. The value of this ratio to which each curve corresponds is marked at the lower ends. Thus, in a shaft of which

the inner diameter is .6 of the outer, the shearing stress at P_2 is $\mathbf{S}_2$.

OL_0 is the maximum shearing stress for the solid shaft. But when a hole of one-tenth of the outside diameter is bored axially, the maximum shearing stress E_1L_1 is raised to practically twice OL_0. The support which was given by the metal now removed has to be supplied principally by that in the immediate vicinity of the hole. Thus, if the hole is infinitesimal, it can readily be shown from equation (37) that the maximum shearing stress is exactly double what it would be if no hole existed. This is one of a class of results—indicated clearly by theory—relating to the effect of the presence of holes, cracks, keyways, &c., on the distribution of shearing stress, which are often (though not in the present case) of great importance, but which have gained no sufficient practical recognition. I will probably revert to the subject in the near future.

Shearing stress is frequently reckoned per square inch of total section, as if it were uniformly distributed. The dotted lines in the quadrant BC', Fig. XXIX, are added to show how false this mode of estimating is. These are numbererd correspondingly to the curves and give, by their distance from Oy, the mean intensity of shearing stress for the corresponding value of r_2/r_1.

The stresses shown by Fig. XXIX are read from its scale in the same way as for the previous figure.

As the longitudinal stresses produced by X are a maximum at A and B, and zero along Oy, the shearing stresses have little effect in raising the total stress, unless the bar is very short; but, when it is also subjected to torsion, the shearing stress thus produced adds directly to that given in Figs. XXVIII and XXIX, all round the circumference. Therefore, when the bar is short, the total stress may be very sensibly raised and the position of the maximum shifted considerably from A.

Appendix C.

ON THE FLEXURAL RIGIDITY OF THE CRANK SHAFTS.

In treating the question of want of alignment it was necessary to estimate approximately the influence which the webs had on

TABLE XXX.—FLEXURAL RIGIDITY OF THE CRANK SHAFTS, FIG. VIII—STEAM ALONE.

Line	F_m	10	20	30	40	50	60	70	80	90	100
(a)	Angular displacement of shaft at center of bearing A, in circular measure multiplied by 10^8	315	356	386	411	430	448	464	476	489	500
(b)	Angular displacement as in line (a), but with webs removed and replaced by pieces of shaft of same diameter as main journal	119	181	230	273	311	344	376	402	429	453
(c)	Factor for influence of webs = line (a) ÷ line (b)	2.65	1.97	1.68	1.51	1.38	1.30	1 23	1.18	1.14	1.10
(d)	Rise in length of bearing A per one inch stroke of engine, multiplied by 10^8 = line (a) multiplied by length of bearing A in inches per one inch stroke	41 5	74.0	104.7	134-4	162.5	190.6	217.9	243.6	269.8	295.1

TABLE XXXI.—FLEXURAL RIGIDITY OF CRANK SHAFTS, FIGS. XIV TO XXI—STEAM AND INERTIA.

Line.		F_m.	10	20	40	60	80	100
(a_1)	$\frac{a}{d}=2.$	Angular displacement of shaft at center of bearing A, in circular measure multiplied by 10^6.	324	359	407.5	442	469	491.8
(b_1)		Angular displacement as in line (a_1), but with webs removed and replaced by pieces of shaft of same diameter as main journal	112.3	167	247.5	310	363	408.4
(c_1)		Factor for influence of webs = line (a_1) ÷ line (b_1)	2.89	2.15	1.65	1.43	1.29	1.20
(d_1)		Rise in length of bearing A per one inch stroke of engine, multiplied by 10^6 = line (a_1), multiplied by length of bearing A in inches per one inch stroke	27	47	84	119	152	185
(a_2)	$\frac{a}{d}=5.$	Angular displacement of shaft at center of bearing A, in circular measure multiplied by 10^6	562	641	730	783	818	842
(b_2)		Angular displacement as in line (a_2), but with webs removed and replaced by pieces of shaft of same diameter as main journal	244	360	515	626	710	781
(c_2)		Factor for influence of webs = line (a_2) ÷ line (b_2)	2.30	1.78	1.42	1.25	1.15	1.08
(d_2)		Rise in length of bearing A per one inch stroke of engine, multiplied by 10^6 = line (a_2) multiplied by length of bearing A in inches per one inch stroke	73	132	235	327	410	485
(a_3)	$\frac{a}{d}=8.$	Angular displacement of shaft at center of bearing A, in circular measure multiplied by 10^6	773	882	976	1,020	1,042	1,054
(b_3)		Angular displacement as in line (a_3), but with webs removed and replaced by pieces of shaft of same diameter as main journal	382	546	745	879	980	1,056
(c_3)		Factor for influence of webs = line (a_3) ÷ line (b_3)	2.02	1.62	1.31	1.16	1.06	1.00
(d_3)		Rise in length of bearing A per one inch stroke of engine, multiplied by 10^6 = line (a_3) multiplied by length of bearing A in inches per one inch stroke	134	240	413	556	679	787
(a_4)	$\frac{a}{d}=10.$	Angular displacement of shaft at center of bearing A, in circular measure multiplied by 10^6	899	1,009	1,092	1,125	1,135	1,138
(b_4)		Angular displacement as in line (a_4), but with webs removed and replaced by pieces of shaft of same diameter as main journal	468	653	873	1,012	1,111	1,193
(c_4)		Factor for influence of webs = line (a_4) ÷ line (b_4)	1.92	1.55	1.25	1.11	1.02	.95
(d_4)		Rise in length of bearing A per one inch stroke of engine, multiplied by 10^6 = line (a_4) multiplied by length of bearing A in inches per one inch stroke	180	315	508	698	838	962

the flexibility of the shaft. The manner of doing this has been shortly explained on page 704, Volume VIII. Only the following need be added to what is said there. To find roughly the actual magnitude of the angular displacement at bearing *A*, instead of supposing one pound applied to the crank pin I took,—

For steam alone, .99 F_m. Table II.

For steam and inertia, .471 $F_m + 1.148\ G$. Table XV.

The slight clearance between the main bearing and web was neglected.

The pressure was supposed to be distributed over the whole length of the crank pin.

The length of the web taken as subject to flexure was half the stroke of the engine diminished by one quarter of the sum of the crank pin and main journal diameters.

Young's modulus, E, was taken $= 30 \times 10^6$ pounds per square inch.

The results are shown in Tables XXX and XXXI, which require no further explanation.

Appendix D.

On the Equilibrium of a Continuous Girder. Theorem of Three Moments when the Supports are Slightly out of Line, with Applications to Crank Shafts.

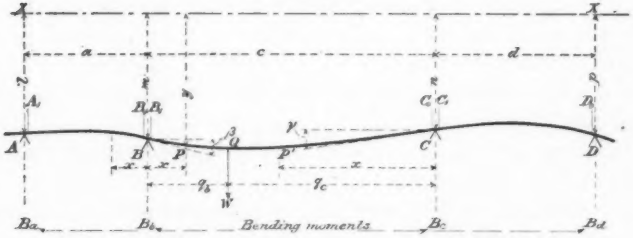
The supports are all supposed to be in one vertical plane. The extension of Clapeyron's Theorem of Three Moments to this case only requires a different determination of the constants of integration from that for the supports in line, given in Mr. Love's Treatise [§222]. The present case seems to be treated in M. Levy's *Statique Graphique*, t. II [§223].

The curved line *ABCD*, Fig. XXX, represents a portion of a continuous girder supported at the four points *A*, *B*, *C*, *D*, which are slightly out of line. The distances of these points below the straight base line XX, which we may suppose horizontal, are l, m, n, p, respectively.

The beam is supposed massless, of uniform flexural rigidity,

and straight when free from constraint of the supports or applied load. It is curved by a load W applied at Q, between B and C.

Fig. XXX.



Let the horizontal distance from A to B be $= a$.
Let the horizontal distance from B to C be $= c$.
Let the horizontal distance from C to D be $= d$.
Let the horizontal distance from B to Q be $= q_b$.
Let the horizontal distance from Q to C be $= q_c$.
In span AB measure x from B to left.
In part span BQ measure x from B to right.
In part span CQ measure x from C to left.
Measure y, in all cases, downward from XX.
Let the tangents at B and C make angles β and γ with XX.

B_0 and B_1 are the shearing forces immediately to the left and right of the support B. The shearing forces at the other supports are similarly designated.

The bending moments at A, B, C and D are given by B_a, B_b, B_c, B_d.

The previous conventions with regard to positive forces and moments are retained; that is, forces acting downward are positive and moments are positive when the upper fibers are in tension.

$$\mathrm{F} = IE, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (40)$$

where F = the flexural rigidity of the beam, I the moment of inertia of the cross-section about a horizontal line through the center of figure, and E Young's modulus.

P and P' are any points (x, y) in BQ and CQ respectively.

Taking moments about P we find the equation of moments for BP is

$$\mathrm{F}\frac{d^2y}{dx^2} - B_b - B_1x = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

Similarly the equation of moments for CP' is

$$\mathrm{F}\frac{d^2y}{dx^2} - B_c - C_0x = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

From equation (41), by integration,

$$\mathrm{F}\frac{dy}{dx} - B_bx - \frac{1}{2}B_1x^2 + k_1 = 0,$$

where k_1 is a constant of integration.

When $x = 0$, $\frac{dy}{dx} = tan\,\beta$. Thus

$$\mathrm{F}\left(\frac{dy}{dx} - tan\,\beta\right) - B_bx - \frac{1}{2}B_1x^2 = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (43)$$

Similarly, from equation (42),

$$\mathrm{F}\left(\frac{dy}{dx} - tan\,\gamma\right) - B_cx - \frac{1}{2}C_0x^2 = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

From equation (43), by integration,

$$\mathrm{F}\,(y - x\,tan\,\beta) - \frac{1}{2}B_bx^2 - \frac{1}{6}B_1x^3 + k_2 = 0.$$

When $x = 0$, $y = m$. Thus

$$\mathrm{F}\,(y - m - x\,tan\,\beta) - \frac{1}{2}B_bx^2 - \frac{1}{6}B_1x^3 = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

Similarly, from equation (44),

$$\mathrm{F}\,(y - n - x\,tan\,\gamma) - \frac{1}{2}B_cx^2 - \frac{1}{6}C_0x^3 = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad (46)$$

$x = q_b$ in equation (43), and $x = q_c$ in equation (44), make the values of dy/dx equal but of opposite sign. Thus

$$\mathrm{F}\,(tan\,\beta + tan\,\gamma) = -B_bq_b - B_cq_c - \frac{1}{2}B_1q_b^2 - \frac{1}{2}C_0q_c^2. \quad . \quad (47)$$

$x = q_b$ in equation (45), and $x = q_c$ in equation (46), give the same value of y. Thus

$$\mathrm{F}(m - n + q_b \tan\beta - q_c \tan\gamma) = -\frac{1}{2} B_b q_b^2 + \frac{1}{2} B_c q_c^2 - \frac{1}{6} B_1 q_b^3 + \frac{1}{6} C_0 q_c^3. \quad . \quad . \quad . \quad (48)$$

Taking moments about C and B, we get

$$\left.\begin{aligned} B_1(q_b + q_c) + Wq_c + B_b - B_c &= 0, \\ C_0(q_b + q_c) + Wq_b - B_b + B_c &= 0. \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

Eliminating B_1, C_0, and $\tan\gamma$ by equations (47), (48) and (49), we get

$$\mathrm{F}(q_b + q_c)\tan\beta = -\mathrm{F}(m - n) + \frac{1}{6} Wq_b q_c (q_b + 2q_c) - \frac{1}{6}(2B_b + B_c)(q_b + q_c)^2. \quad . \quad . \quad . \quad (50)$$

We may similarly deduce an equation containing $\tan\beta$, for the span AB which has no load. Or, more simply, we may transform equation (50). Thus, writing a for $q_b + q_c$, $-\tan\beta$ for $+\tan\beta$, and putting $W = 0$; also replacing n and B_c by l and B_a, respectively, we get,

$$\mathrm{F}a\tan\beta = \mathrm{F}(m - l) + \frac{1}{6}(2B_b + B_a)a^2. \quad . \quad . \quad . \quad (51)$$

Eliminating $\tan\beta$ by equations (50) and (51) we get

$$6\,\mathrm{F}\{a(m - n) + (q_b + q_c)(m - l)\} + a^2(q_b + q_c)(2B_b + B_a) + a(q_b + q_c)^2(2B_b + B_c) = Waq_b q_c(q_b + 2q_c). \quad . \quad . \quad (52)$$

This is the Theorem of Three Moments for the case considered.

1st Case.—$a = c = d = 2q_b = 2q_c = b$.

This is the case of the bar, Fig. VI. Equation (52) becomes,

$$48\,\mathrm{F}(2m - l - n) + 8b^2(4B_b + B_a + B_c) = 3Wb^3. \quad . \quad . \quad . \quad (53)$$

By simple transpositions we can readily find from equation (53) the values of B_b and B_c for F_1 applied in span CD, F_2 in span BC, and F_3 in span AB, as in Fig. IV—the conditions $B_a = B_d = 0$ being retained.

F_1 acting alone—spans AB, BC under no applied load. Equation (53) becomes

$$48\,\mathrm{F}\,(2m - l - n) + 8b^2\,(4B_b + B_c) = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (54)$$

For spans BC and CD we must change l, m, n, a, b, c, W, into m, n, p, b, c, d, F_1 respectively, and put $B_d = 0$. Equation (53) becomes

$$48\,\mathrm{F}\,(2n - m - p) + 8b^2\,(4B_c + B_b) = 3F_1b^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad (55)$$

Equations (54) and (55) give

$$B_b = \frac{4\mathrm{F}}{10b^2}(4l - 9m + 6n - p) - \frac{1}{40}F_1b. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (56)$$

We see at once from any of the equations (52), (53) or (56) that the bending moments induced by want of alignment of the bearings are entirely independent of those arising from the applied load, and merely added to them. For the bearings in line $l - m = m - n = n - p$, and the first term on the right hand of equation (56) vanishes, as it should. This leaves

$$B_b = -.025F_1b,$$

which agrees with equation (10). Similarly, equations (11) and (12) may be deduced from equation (53).

Before returning to the consideration of the effect of want of alignment, I will give the deduction of the expression on page 327, Volume IX, for the pressure, f_B, on bearing B. Taking moments about C, Fig. VI, we have

$$b\left(2f + \frac{3}{2}F_3 + f_B + \frac{1}{2}F_2\right) = B_c.$$

Substituting for B_c and f their values in equations (13) and (14) we get

$$f_B = \frac{1}{40}(6F_1 - 23F_2 - 29F_3),$$

as already given.

From equation (56), the value of B_b due to want of alignment is,

$$B_b = \frac{4\mathrm{F}}{10b^2}(4l - 9m + 6n - p).$$

This expression was, for brevity, got while supposing F_1 acting alone; but as it is independent of applied load the same expression for this part of B_b would have arisen whatever supposition had been made. If f_a is the reaction at bearing A from want of alignment alone we have,—taking moments about B—

$$b \times f_a = B_b = \frac{4\mathrm{F}}{10b^2}(4l - 9m + 6n - p)$$

or

$$f_a = \frac{4\mathrm{F}}{10b^3}(4l - 9m + 6n - p). \quad . \quad . \quad . \quad . \quad (57)$$

$I = \frac{\pi a^4}{64}$, for a *solid* bar of diameter a. $E = 30 \times 10^6$ and $\mathrm{F} = IE = \frac{\pi \times 30 \times 10^6 a^4}{64}$.

Thus equation (57) becomes,

$$f_a = \frac{.589 \times 10^6 \times a^4}{b^3}(4l - 9m + 6n - p).$$

This agrees with expression (15) in all but the sign. The change is due to shifting the base line from below to above the bar.

A bar with an axial hole of half the outside diameter has a value of f_a which is 15/16 of that just given. But as there are several indefinite conditions in the problem of the effect of want of alignment, it was thought better to leave the larger figure. The stiffer the shaft is, the smaller will be the error of bearings at which the stresses given in the various tables will be produced.

2d Case.—Bearing B removed and the other bearings in line. AC then becomes one span of length $2b$, with forces applied at the two points E and F, Fig. VI. $CD = b$.

F_1 acting alone.—In equation (52) we must write $a = 2b$, $q_b = q_c = b/2$; change b and c into c and d, respectively, and make $B_a = B_d = 0$. The term due to want of alignment obviously becomes zero.

We get,

$$B_c = F_1 b/16.$$

F_2 acting alone.—We must write $a = b$, $q_b = b/2$, $q_c = 3b/2$; change b and c into c and d, respectively, and make $B_a = B_d = 0$.

We get,

$$B_c = 7F_2b/32.$$

Similarly, for F_3 acting alone we get,

$$B_c = 5F_3b/32.$$

Thus the total value of B_c is

$$B_c = \frac{b}{32}(2F_1 + 7F_2 + 5F_3)$$

as given in Volume VIII, page 715.

Taking moments about C,

$$b\left(2f + \frac{3}{2}F_3 + \frac{1}{2}F_2\right) = B_c = \frac{b}{32}(2F_1 + 7F_2 + 5F_3).$$

From which,

$$f = \frac{1}{64}(2F_1 - 9F_2 - 43F_3), \quad . \quad . \quad . \quad . \quad . \quad (58)$$

as was also previously given.

Let us now calculate the deflection for this case at the point B. Measure x from C to left, in Fig. VI.

The equation of moments for the part span AE, Fig. VI, is

$$\mathrm{F}\frac{d^2y}{dx^2} - f(2b - x) = 0;$$

from which

$$\left.\begin{aligned} \mathrm{F}\frac{dy}{dx} - f\left(2bx - \frac{1}{2}x^2\right) + k_1 &= 0, \\ \text{and } \mathrm{F}y - f\left(bx^2 - \frac{1}{6}x^3\right) + k_1x + k_2 &= 0, \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (59)$$

where k_1 and k_2 are constants of integration.

Similarly, for the part span EF,

$$\mathrm{F}\frac{d^2y}{dx^2} - f(2b - x) - F_3\left(\frac{3}{2}b - x\right) = 0$$

from which

$$\left.\begin{aligned} \mathrm{F}\frac{dy}{dx} - f\left(2bx - \tfrac{1}{2}x^2\right) - F_3\left(\tfrac{3}{2}bx - \tfrac{1}{2}x^2\right) + k_3 = 0, \\ \text{and } \mathrm{F}y - f\left(bx^2 - \tfrac{1}{6}x^3\right) - F_3\left(\tfrac{3}{4}bx^2 - \tfrac{1}{6}x^3\right) + k_3x + k_4 = 0, \end{aligned}\right\} \quad (60)$$

Similarly, for the part span FC,

$$\mathrm{F}\frac{d^2y}{dx^2} - f(2b - x) - F_3\left(\tfrac{3}{2}b - x\right) - F_2\left(\tfrac{1}{2}b - x\right) = 0,$$

from which

$$\left.\begin{aligned} \mathrm{F}\frac{dy}{dx} - f\left(2bx - \tfrac{1}{2}x^2\right) - F_3\left(\tfrac{3}{2}bx - \tfrac{1}{2}x^2\right) \\ - F_2\left(\tfrac{1}{2}bx - \tfrac{1}{2}x^2\right) + k_5 = 0, \\ \text{and } \mathrm{F}y - f\left(bx^2 - \tfrac{1}{6}x^3\right) - F_3\left(\tfrac{3}{4}bx^2 - \tfrac{1}{6}x^3\right) \\ - F_2\left(\tfrac{1}{4}bx^2 - \tfrac{1}{6}x^3\right) + k_5x + k_6 = 0. \end{aligned}\right\} \quad (61)$$

In equation (59), where $x = 2b$, $y = 0$.

In equations (59) and (60), where $x = \frac{3}{2}b$, the y's and dy/dx's are equal.

In equations (60) and (61), where $x = \frac{1}{2}b$, the y's and dy/dx's are equal.

In equation (61), where $x = o$, $y = 0$.

These six conditions allow us to determine the integration constants k_1 to k_6 in equations (59), (60) and (61). Putting the values of k_3 and k_4 so found in the second of equations (60), and giving f its value in equation (58), we find the value, Y_B, of y at the point B, for which $x = b$.

$$\frac{\mathrm{F}Y_B}{b^3} = \frac{1}{384}(-6F_1 + 23F_2 + 29F_3). \quad . \quad . \quad . \quad (62)$$

Putting,

$$F = \frac{\pi \times 30 \times 10^6 \times a^4}{64}, \text{ we get}$$

$$Y_B = \frac{1.768 \times 10^{-9} b^3}{a^4}(-6F_1 + 23F_2 + 29F_3),$$

which agrees with equation (24).

Suppose any of the crank webs vertical and stressed by a moment M produced by the vertical reactions on the main bearings and crank pins, thus bending it in a vertical longitudinal plane. The center line of the web will be bent to a uniform curvature. If ρ is the radius of curvature we have

$$\frac{M}{IE} = \frac{1}{\rho},$$

which measures the angular deflection per unit length of web.

Suppose now the shaft turned till the web is horizontal and the same moment applied. If τ is the angle of torsion per unit length of web we have

$$\frac{M}{\mu\tau} = \eta.$$

The numerical values of η are given in the last line of Table XXIX for a rectangular prism with short side = one inch and long side as noted in the top line; that is, with the notation in Fig. IV, &c., $e = 1$ and ε (= $2a$ of Table XXIX) as given.

Then $I = \varepsilon/12$.

The ratio of these angular displacements is

$$\tau\rho = \frac{IE}{\mu\eta}.$$

Putting $E = 30 \times 10^6$, $\mu = 12 \times 10^6$ and for I its value just given, we have,

$$\tau\rho = \frac{\varepsilon}{4.8\eta}. \quad \ldots\ldots\ldots \quad (63)$$

Table XXXII gives the values of this ratio for $\varepsilon = 1.5, 1.6, \ldots, 2.3$.

TABLE XXXII.—RATIO OF FLEXURAL TO TORSIONAL RIGIDITY OF CRANK WEBS.

Thickness of web fore and aft = 1 inch.

Breadth of web in inches	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3
η, from Table XXIX	.2936	.3260	.3586	.3914	.4243	.4574	.4905	.5237	.5569
Ratio of flexural to torsional rigidities, equation (63)	1.064	1.022	.988	.958	.933	.911	.892	.875	.860

Thus for the ordinary proportions of breadth to thickness of webs the flexural and torsional rigidities are practically equal. As the lengths under torsion and crossbending are the same, if this ratio were unity any moment M would induce the same angle between the center lines of the crank pin and main journal, where they join the web, whether it is applied in, or normal to, the plane of the webs.

From this it readily follows that the change of angle is the same however the planes of the couple and webs are inclined to one another.

Let τ_1 be the angle induced per unit couple, by crossbending or torsion; thus

$$\tau_1 = \frac{\tau}{M} \times \text{length of web under flexure.}$$

Suppose, as before, M to be in the vertical plane while the webs are inclined at an angle θ to the vertical. We have,—

Couple producing crossbending $= M\cos\theta$.

Couple producing torsion $= M\sin\theta$.

Angle from crossbending $= M\tau_1\cos\theta$, in plane of webs.

Angle from torsion $= M\tau_1\sin\theta$, normal to plane of webs.

Projection of angle from crossbending, in vertical plane, $= M\tau_1\cos^2\theta$.

Projection of angle from torsion, in vertical plane, $= M\tau_1\sin^2\theta$.

Total angle in vertical plane $= M\tau_1(\cos^2\theta + \sin^2\theta) = M\tau_1$.

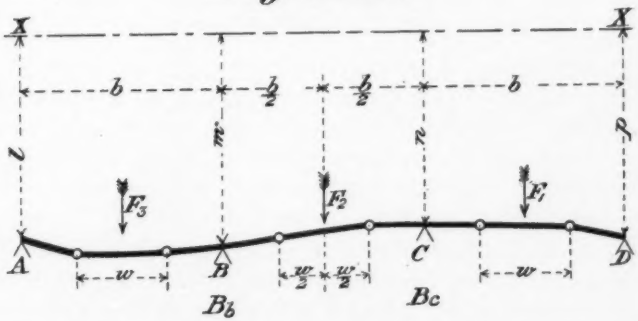
This proves the proposition.

Similarly it may be shown that the change of angle in the horizontal plane is zero; or, more generally,—Where the flexural and torsional rigidities are equal the total angular change is parallel to the plane of the couple, and is independent of the inclination of that plane to the plane of the webs.

On this result may be founded a much more accurate solution of the crank shaft problem. I will only state the result.

As the effect of torsion arising from the turning moments is not taken into account, for reasons sufficiently explained in the body of the paper, we may represent the crank shaft very closely by the elastic beam shown in Fig. XXXI. The lettering is as in Fig. VI, and the added circles indicate the longitudinal position of the centers of the webs. The conditions supposed allow us to look on the webs merely as joints controlled by stiff springs.

Fig. XXXI.



Let the distances of the web centers $= w$ ($w = 2K_1$ of Fig IV); the webs being, of course, placed at equal distances on each side of the engine centers.

The flexural rigidity of the shaft is F; the resistance of the web to flexure is $1/\tau_1$.

The distribution of bending moments and reactions on main bearings depends, when the bearings are in line, on the ratio of those two rigidities; that is on $\mathfrak{C}$, where

$$\mathfrak{C} = \mathrm{F}\tau_1, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (64)$$

For the bearings in line we find that the two relations between B_b and B_c are,

$$\mathfrak{C}\left\{\frac{b^2-w^2}{b^3}B_b+\frac{2(b^2+w^2)}{b^3}B_c-\frac{b-w}{2b}(F_1+F_2)\right\}$$
$$+\frac{1}{3}(B_b+4B_c)=\frac{b}{8}(F_1+F_2). \quad . \quad . \quad . \quad (65)$$

$$\mathfrak{C}\left\{\frac{2(b^2+w^2)}{b^3}B_b+\frac{b^2-w^2}{b^3}B_c-\frac{b-w}{2b}(F_2+F_3)\right\}$$
$$+\frac{1}{3}(4B_b+B_c)=\frac{b}{8}(F_2+F_3). \quad . \quad . \quad . \quad (66)$$

The values of B_b and B_c, due to want of alignment, are given by

$$B_b\left\{4+\frac{6\mathfrak{C}(b^2+w^2)}{b^3}\right\}+B_c\left\{1+\frac{3\mathfrak{C}(b^2-w^2)}{b^3}\right\}$$
$$=\frac{6\mathfrak{F}}{b^2}(l-2m+n). \quad . \quad . \quad . \quad (67)$$

$$B_b\left\{1+\frac{3\mathfrak{C}(b^2-w^2)}{b^3}\right\}+B_c\left\{4+\frac{6\mathfrak{C}(b^2+w^2)}{b^3}\right\}$$
$$=\frac{6\mathfrak{F}}{b^2}(m-2n+p). \quad . \quad . \quad . \quad (68)$$

When $\mathfrak{C}=0$, equations (65) to (68) give values of B_b and B_c corresponding with those found before. It is from these equations the results noted on pages 683 and 704, Volume VIII, were deduced.

In calculating τ_1 the same length of web was considered under flexure as in Appendix C.

To compensate very approximately for the fore and aft thickness of the webs being reduced to zero in Fig. XXXI, the angle τ_1 was taken as equal to the angle through which the center line of the web would be bent by unit couple, diminished by the angle through which unit couple would bend the center line of a shaft of the same diameter as the main journal and of a length equal to the fore and aft thickness of the webs.

The deduction of equations (65) to (68) is very similar to the earlier investigation in this appendix.

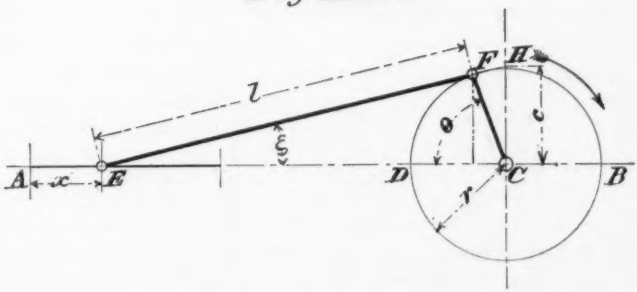
It should be noted that both in this appendix and in the previous one, the small change in direction of the center line of the bar which takes place at those points where shearing stress changes, is omitted. This quantity has usually been overlooked when investigating deflection. Taking account of it would slightly diminish the factor for the influence of the webs in Appendix C. In this appendix it would usually have added a little to the flexibility of the shafts.

Appendix E.

Analysis of the inertia forces of the parts attached to the crank pin of an engine, with method of describing curves.

In Fig. XXXII, let AB be the straight line passing through the centers of the cylinder and crank shaft; C the center of the crank shaft; EF the connecting rod; CF the crank; A the limit of travel of the point E, when the crank coincides with CD; and DFB the crank circle. Let the angle $ACF = \theta$; $CF = r$; and $EF = l$. The point E has moved a distance $AE = x$, and the connecting rod is inclined to AB at an angle ζ.

Fig. XXXII.



We will suppose that the crank CF revolves at a uniform rate.

$$AC = AD + DC;$$

but AD and DC are the positions of the crank and connecting rod when $\theta = 0$; therefore,

$$AC = r + l.$$

$CE = r\cos\theta + l\cos\zeta$, but also
$CE = AC - AE = r + l - x$,
therefore $r + l - x = r\cos\theta + l\cos\zeta$,

$$\text{or } \frac{x}{r} = 1 + \frac{l}{r} - \cos\theta - \frac{l}{r}\cos\zeta. \quad . \quad . \quad . \quad (69)$$

Again

$$r\sin\theta = l\sin\zeta.$$

If $\frac{r}{l} = a$, this becomes $\sin\zeta = a\sin\theta$;

and

$$\cos\zeta = \sqrt{\{1 - a^2\sin^2\theta\}}$$
$$= 1 - \frac{1}{2}a^2\sin^2\theta - \frac{1}{8}a^4\sin^4\theta - \frac{1}{16}a^6\sin^6\theta - \&c.$$

Substituting in equation (69) we get

$$\frac{x}{r} = 1 + \frac{1}{a} - \cos\theta - \frac{1}{a}\left\{1 - \frac{1}{2}a^2\sin^2\theta - \frac{1}{8}a^4\sin^4\theta - \frac{1}{16}a^6\sin^6\theta - \right\}$$
$$= 1 - \cos\theta + \frac{1}{2}a\sin^2\theta + \frac{1}{8}a^3\sin^4\theta + \frac{1}{16}a^5\sin^6\theta + \quad . \quad . \quad . \quad . \quad (70)$$

We may now apply the following well known formulas:—

$$2\sin^2\theta = 1 - \cos 2\theta.$$
$$2^3\sin^4\theta = 3 - 4\cos 2\theta + \cos 4\theta.$$
$$2^5\sin^6\theta = 10 - 15\cos 2\theta + 6\cos 4\theta - \cos 6\theta.$$
$$\&c. \qquad\qquad \&c.$$

Substituting these in equation (70) and collecting the terms we finally get,

$$\left.\begin{aligned}
\frac{x}{r} = \quad & 1 + \frac{1}{4}a + \frac{3}{64}a^3 + \frac{5}{256}a^5 + \\
& -\cos\theta \\
& -\cos 2\theta\left(\frac{1}{4}a + \frac{1}{16}a^3 + \frac{15}{512}a^5 + \right) \\
& +\cos 4\theta\left(\quad + \frac{1}{64}a^3 + \frac{3}{256}a^5 + \right) \\
& -\cos 6\theta\left(\qquad\quad + \frac{1}{512}a^5 + \right) \\
& \text{\&c.} \qquad\qquad \text{\&c.}
\end{aligned}\right\} \quad . \quad . \quad (71)$$

When the shaft is revolving uniformly, that is when θ increases uniformly with the time, each expression such as $A_1\cos\theta$, $A_2\cos 2\theta$, $A_3\cos 3\theta$, &c., represents a simple harmonic motion. $A_1\cos\theta$ goes through a complete cycle of changes during one revolution of the engine. As $A_2\cos 2\theta$ has the same values for the positions of the crank CF which differ by 180°, this simple harmonic motion goes through two complete cycles of changes in one revolution of the engine. It is, therefore, said to have a period equal to half that of the engine; and so on for the other simple harmonic motions. Obviously A_1 is the maximum value of the term $A_1\cos\theta$.

Equation (71) shows that the movement of the point E may be represented as the sum of an infinite number of simple harmonic motions of different periods and amplitudes. Also, that besides the simple harmonic motion of the same period as the engine, represented by the term $-r\cos\theta$, we have only simple harmonic motions of a shorter period, and each of those periods is an even submultiple of that of the engine. Further, all the component motions come to a maximum when the crank pin F passes the dead points D and B.

Now, if ω is the angular velocity of the crank in radians per second, we have $\omega = d\theta/dt$, where t is the time.

Also, if v is the velocity of E we have

$$v = \frac{dx}{dt} = \frac{dx}{d\theta} \cdot \frac{d\theta}{dt} = \omega \frac{dx}{d\theta}.$$

Thus, differentiating equation (71), we find

$$\left.\begin{aligned}\frac{v}{r\omega} &= sin\theta \\ &+ sin2\theta\left(\tfrac{1}{2}a + \tfrac{1}{8}a^3 + \tfrac{15}{256}a^5 + \right) \\ &- sin4\theta\left(+ \tfrac{1}{16}a^3 + \tfrac{3}{64}a^5 + \right) \\ &+ sin6\theta\left(+ \tfrac{3}{256}a^5 + \right).\end{aligned}\right\} \quad . \quad . \quad . \quad (72)$$

If a is the acceleration of the point E, we get from equation (72) by differentiation,

$$a = \frac{dv}{dt} = \frac{dv}{d\theta}\cdot\frac{d\theta}{dt} = \omega\frac{dv}{d\theta},$$

or

$$\left.\begin{aligned}\frac{a}{r\omega^2} &= cos\theta \\ &+ cos2\theta\left(a + \tfrac{1}{4}a^3 + \tfrac{15}{128}a^5 + \right) \\ &- cos4\theta\left(\tfrac{1}{4}a^3 + \tfrac{3}{16}a^5 + \right) \\ &+ cos6\theta\left(\tfrac{9}{128}a^5 + \right).\end{aligned}\right\} \quad . \quad . \quad (73)$$

The force exerted by a mass m having the same motion as the point E is $\frac{ma}{g}$ in gravitation units, and can thus be calculated at once from equation (73).

We notice that equation (73) gives,—

When $\theta = 0$, $\frac{a}{r\omega^2} = 1 + a$.

When $\theta = \pi$, $\frac{a}{r\omega^2} = 1 - a$.

And the corresponding forces are,—

When $\theta = 0$, $\quad \frac{m\omega^2 r}{g}(1 + a)$.

When $\theta = \pi$, $-\frac{m\omega^2 r}{g}(1 - a)$.

This is well known already.

If the center line of the connecting rod EF, produced if necessary, cuts the line drawn through C at right angles to AB, at H; and if $HC = c$; then a force F applied at E along the line AB will produce a turning moment $= Fc$. And the length HC represents the linear velocity of E to the same scale as r does that of F. But as the linear velocity of $F = \omega r$ we get,

$$v = \omega c \text{ or } \frac{c}{r} = \frac{v}{\omega r}.$$

These statements we need not stop to prove as they are also well known.

We thus have from equation (72),

$$\left.\begin{aligned} \frac{c}{r} &= \sin\theta \\ &+ \sin 2\theta \left(\frac{1}{2}a + \frac{1}{8}a^3 + \frac{15}{256}a^5 + \right) \\ &- \sin 4\theta \left(\quad + \frac{1}{16}a^3 + \frac{3}{64}a^5 + \right) \\ &+ \sin 6\theta \left(\qquad + \frac{3}{256}a^5 + \right). \end{aligned}\right\} \quad . \quad . \quad . \quad (74)$$

If T is the turning moment due to the inertia of m we have,

$$T = -\frac{mac}{g}.$$

Multiplying equations (73) and (74) we express the variable part of this moment thus,

$$\begin{aligned} \frac{ac}{\omega^2 r^2} &= (\cos\theta + A_2\cos 2\theta + A_4\cos 4\theta +) \\ &\quad \times (\sin\theta + B_2\sin 2\theta + B_4\sin 4\theta +), \end{aligned}$$

where $A_2, A_4, \ldots, B_2, B_4, \ldots$ are the functions of a given in equations (73) and (74).

By multiplication, and substitution of

$$\sin(m+n)\theta + \sin(m-n)\theta \text{ for } 2\sin m\theta\cos n\theta,$$

we get,

$$\frac{ac}{\omega^2 r^2} = sin\theta \left(+ \frac{1}{4}a + \frac{1}{16}a^3 + \frac{15}{512}a^5 + \right)$$
$$- sin2\theta \left(\frac{1}{2} + 0 \times a^2 + \frac{1}{32}a^4 + \frac{1}{32}a^6 + \right)$$
$$- sin3\theta \left(+ \frac{3}{4}a + \frac{9}{32}a^3 + \frac{81}{512}a^5 + \right)$$
$$- sin4\theta \left(+ \frac{1}{4}a^2 + \frac{1}{8}a^4 + \frac{1}{16}a^6 + \right)$$
$$+ sin5\theta \left(+ \frac{5}{32}a^3 + \frac{75}{512}a^5 + \cdot \right)$$
$$+ sin6\theta \left(\frac{3}{32}a^4 + \frac{3}{32}a^6 + \right)$$
$$- sin7\theta \left(\frac{21}{512}a^5 + \right)$$
$$- sin8\theta \left(\frac{1}{32}a^6 + \right). \quad . \quad . \quad . \quad (75)$$

For any values of a in practice, the series which form the co-efficients of the sines and cosines of θ and its multiples are seen to be all highly convergent.

For any given value of a it becomes a very simple matter to calculate the value of the co-efficients and thus follow the fluctuations of the various functions given by the above equations.

Suppose the connecting rod, center to center, is four cranks in length, or $a = .25$. We get,

$$\frac{x}{r} = 1.0632 - cos\theta - .0635cos2\theta + .0002cos4\theta. \quad . \quad . \quad . \quad . \quad (76)$$

$$\frac{v}{r\omega} = sin\theta + .1270sin2\theta - .0010sin4\theta. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (77)$$

$$\frac{a}{r\omega^2} = cos\theta + .2540cos2\theta - .0041cos4\theta + .00007cos6\theta. \quad . \quad . \quad (78)$$

$$\frac{c}{r} = sin\theta + .1270sin2\theta - .0010sin4\theta. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (79)$$

$$\left.\begin{aligned} \frac{ac}{\omega^2 r^2} = {} & + .0635sin\theta - .5001sin2\theta - .1920sin3\theta \\ & - .0161sin4\theta + .0026sin5\theta + .0004sin6\theta. \end{aligned}\right\} \quad . \quad . \quad . \quad (80)$$

For an engine having a connecting rod equal to five cranks, $a = .2$ and the expression for the acceleration becomes

$$\frac{a}{r\omega^2} = cos\theta + .2020cos2\theta - .0021cos4\theta + .00002cos6\theta. \quad . \quad . \quad (81)$$

It will be noticed what a marked influence this increased length of the connecting rod has on the accelerations and forces of higher period. Also, comparison of the numerical coefficients of $cos4\theta$, in equations (76) and (78), shows that the ratio of the maximum value of the forces of higher period to the maximum value of the force of first period, is much greater than the ratio of the corresponding displacements.

I will very briefly notice the obvious graphical process which the foregoing formulas suggest. Take for instance $a = .25$ and suppose we wish to lay down a curve of turning moments due to inertia on the crank pin path expanded.

Draw two lines Ox, Oy, (Fig. XXXIII) at right angles, and from O as center, to any desired scale, draw circles with radii equal to the values of the coefficients in the formula for T, or ac,—equation (80)—namely,—

First circle.	Radius = .0635.
Second circle.	Radius = .5001.
Third circle.	Radius = .1920.
Fourth circle.	Radius = .0161.
&c.	&c.

These are marked in Fig. XXXIII as (1), (2), (3), (4), respectively. Next draw radial lines from O, which for convenience may be at equal angular intervals. These are numbered 1, 2, 3, . . . 20, consecutively.

The direction Ox corresponds to the crank at the top center.

Now, in Fig. XXXIV, AB represents the crank path expanded; but, to save space, only short portions of the figure, near top stroke at A and B, are shown. Divide the whole length of the crank path AB into the same number of equal parts as there are radial lines in Fig. XXXIII and number them correspondingly, starting from top stroke.

When the crank is at top center the turning moment is, of course, zero. When the crank is at $O1$, Fig. XXXIII, the numerical value of $+ .0635 sin\theta$, the first term in equation (80), is given by the length of the perpendicular Cc, from the point of

Fig. XXXIII.
Composition of Inertia Turning Moment Curve.
Auxiliary Diagram.

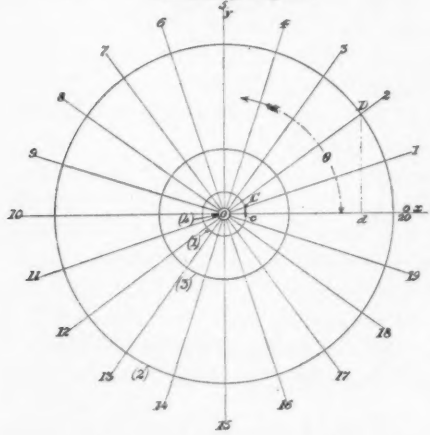
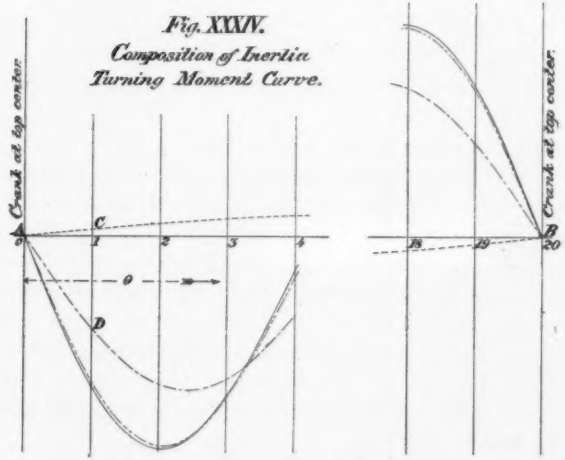


Fig. XXXIV.
Composition of Inertia Turning Moment Curve.



intersection of radial line $O1$ with circle (1), to the line Ox. The coefficient being positive we must measure a distance $1C$ in Fig. XXXIV (equal to Cc, Fig. XXXIII) perpendicularly upward from the point 1 in AB.

The value of the second term, $-.5001\ sin2\theta$, is given by Dd perpendicular to Ox, D being the intersection of the radial line $O2$ with the circle (2). This term being negative and D being on the positive side of Ox, the distance CD ($= Dd$, Fig. XXXIII) must be laid off in Fig. XXXIV from C downward. The continuation of the process is obvious. If any radial line, say $O4$, Fig. XXXIII, is used for the first term, the angle $4Ox$ represents θ. For the second term, which contains $sin2\theta$, the radial line $O8$, Fig. XXXIII, must be used; and for the third term, which contains $sin3\theta$, the radial line $O12$, and so on.

Also, when a term appears in equation (80) with a plus sign, the value of the term, (measured by the corresponding perpendicular) must be treated as positive so long as that perpendicular lies on the positive side of Ox, and negative if on the other side. This rule is, of course, reversed for those terms in equation (80) which have a negative sign.

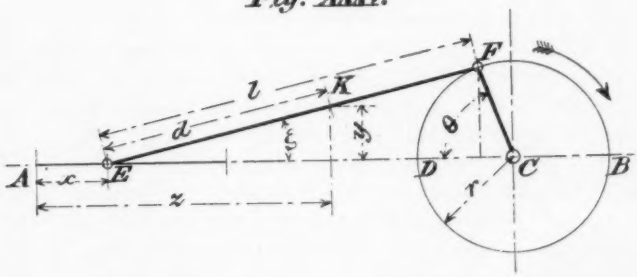
In laying off the curves where terms involving cosines of θ and its multiples occur, the perpendiculars in Fig. XXXIII must be measured to Oy, and a similar convention as to signs used.

This graphical method has the advantage of being perfectly uniform for all periodic functions. I have applied the process frequently in the last six or eight years, and have found it exceedingly easy to draw the various curves to a large scale with accuracy. All the other methods that have been proposed, so far as I recollect, require a diagram of the crank circle and connecting rod, and thus for very accurate curves require a large diagram and much care and labor.

I have, so far, treated only the various functions referring to a mass m moving with the crosshead E, Fig. XXXII. Let us now look at the effect of the inertia of the connecting rod. In Fig. XXXV (in which the lettering is the same as in Fig XXXII) let K be the position of the center of gravity of the connecting rod EF, and let d be its distance from E, which can

easily be calculated from the drawing of the connecting rod in any particular case, or may be determined experimentally by suspending the rod with its length horizontal. We will put R for the mass of the connecting rod, and I for its moment of inertia about the center of gravity K; also, y denotes the distance of the center of gravity, K, from the center line AB, and z its distance from A measured parallel to AB. Let $d/l = \kappa$.

Fig. XXV.



The rod is constrained by the crank and crosshead guides to move in a particular way, and we have to find the forces which must act on it to account for that motion. We are not here dealing with the whole force acting on the connecting rod, but only with those portions of the total forces which are required to account for its change of motion.

For convenience, the differential coefficients with respect to θ will be indicated by the Newtonian notation; that is, $\frac{dx}{d\theta}$ by $\dot{x}$, $\frac{d^2x}{d\theta^2}$ by $\ddot{x}$, and similarly for other functions of θ.

The expressions most important to investigate are:—

(*a*) *The inertia forces parallel to AB.*

(*b*) *The inertia forces at right angles to AB.*

(*c*) *The couple acting on the rod to produce its angular motion.*

(*d*) *The turning moments due to the inertia of the connecting rod.*

Forces are considered positive when they give the rod a positive acceleration. Turning moments on the crank are con-

sidered positive when they tend to accelerate its motion in the direction of the arrow. The angular acceleration of the connecting rod, and the couple producing it, are considered positive when the motion contrary to the hands of a watch is increasing.

(*a*) *The inertia forces parallel to AB.*

$$z = x + d\cos\zeta = x + \kappa l\cos\zeta.$$

But from equation (69), $l\cos\zeta = r + l - x - r\cos\theta$.
Thus

$$z = x + \kappa(r + l - x - r\cos\theta) = \kappa(r + l) + (1 - \kappa)x - \kappa r\cos\theta,$$

and

$$\frac{\ddot{z}}{r} = (1 - \kappa)\frac{\ddot{x}}{r} + \kappa\cos\theta.$$

As $\frac{\ddot{x}}{r} = \frac{a}{r\omega^2}$ we get from equation (73)

$$\frac{\ddot{z}}{r} = \cos\theta + (1 - \kappa)\left\{\begin{array}{l} \cos 2\theta\left(a + \frac{1}{4}a^3 + \frac{15}{128}a^5\right) \\ -\cos 4\theta\left(+ \frac{1}{4}a^3 + \frac{3}{16}a^5\right) \\ +\cos 6\theta\left(+ \frac{9}{128}a^5\right) \end{array}\right\}. \quad (82)$$

The required force is $= \frac{R\ddot{z}\omega^2}{g}$ . . . . . (83)

Thus, we see that for the first period the finite length of the connecting rod does not affect the accelerations and forces. For the higher periods, the maximum values of the accelerations and forces are all reduced from what they would be for a mass R moving with E, in the proportion of FK to FE. This is also obvious from the geometry of the motion.

Thus, when treating the vertical forces for the first period we may suppose the whole moving masses concentrated at F. When treating the higher period forces we may suppose the

connecting rod deprived of mass; and, instead, add to the mass of the parts already moving along with E, a mass equal to that taken from the connecting rod reduced in the proportion of FK to FE.

(*b*) *The inertia forces at right angles to AB.*

$$y = d\sin\zeta = a\sin\theta.$$

Hence, $$\frac{y}{r} = \kappa\sin\theta \text{ and } \frac{\ddot{y}}{r} = -\kappa\sin\theta. \quad . \quad . \quad . \quad . \quad (84)$$

The required force is $$= \frac{R\ddot{y}\omega^2}{g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (85)$$

Thus the horizontal force is only of the first period, and is reduced from what it would be if the whole mass of the connecting rod were concentrated at F, in the proportion of EK to EF. This also is obvious from an inspection of the figure.

(*c*) *The couple acting on the rod to produce its angular motion.*

I being the moment of inertia of the connecting rod about its center of gravity, and $+\frac{d^2\zeta}{dt^2}$ or $+\ddot{\zeta}\omega^2$ being the angular acceleration of the rod, the couple producing its angular motion is

$$= +\frac{I}{g}\ddot{\zeta}\omega^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (86)$$

We have only to evaluate $\ddot{\zeta}$.

$$\sin\zeta = a\sin\theta.$$

Differentiating we get, $\cos\zeta.\dot{\zeta} = a\cos\theta$, or

$$\dot{\zeta} = \frac{a\cos\theta}{\cos\zeta} = a\cos\theta\,(1 - a^2\sin^2\theta)^{-\frac{1}{2}}$$
$$= a\cos\theta\left(1 + \frac{1}{2}a^2\sin^2\theta + \frac{3}{8}a^4\sin^4\theta + \right).$$

Integrating, we get,

$$\zeta = a\sin\theta + \frac{1}{6}a^3\sin^3\theta + \frac{3}{40}a^5\sin^5\theta + .$$

Transforming this in the same way as we did equation (70) we get finally

$$\zeta = \sin\theta \left(a + \frac{1}{8}a^3 + \frac{3}{64}a^5 + \right)$$
$$- \sin 3\theta \left(+ \frac{1}{24}a^3 + \frac{3}{128}a^5 + \right)$$
$$+ \sin 5\theta \left(+ \frac{3}{640}a^5 + \right),$$

and

$$\left.\begin{aligned} \ddot{\zeta} = &- \sin\theta \left(a + \tfrac{1}{8}a^3 + \frac{3}{64}a^5 + \right) \\ &+ \sin 3\theta \left(\tfrac{3}{8}a^3 + \frac{27}{128}a^5 + \right) \\ &- \sin 5\theta \left(+ \frac{15}{128}a^5 + \right). \end{aligned}\right\} \quad . \quad . \quad . \quad (87)$$

Using this value in equation (86) we completely determine the couple.

(*d*) *The turning moments due to the inertia of the connecting rod.*

The inertia force given in equation (83), due to the acceleration of K parallel to AB, produces a force on the crank pin, the resolved part of which parallel to AB is,

$$-\frac{R\omega^2}{g}\ddot{z}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (88)$$

since, neglecting friction, the crank pin is the only part guiding the connecting rod which can apply force in this direction. The turning moment due to this force

$$= -\frac{R\omega^2 r}{g}\ddot{z}\sin\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (89)$$

The force given by equation (83) also induces forces on the crank pin and guide, normal to AB. These must be equal and opposite, and we may find them by taking moments about F. That on the crank pin is

$$= -\frac{R\omega^2}{g}\ddot{z} \times \frac{(l-d)\sin\zeta}{l\cos\zeta}, \quad . \quad . \quad . \quad . \quad . \quad (90)$$

the force on the guide being of opposite sign.

The turning moment induced

$$= -\frac{R\omega^2}{g}\ddot{z} \times \frac{(l-d)\,sin\zeta}{lcos\zeta} \times rcos\theta,$$

which reduces to

$$-\frac{R\omega^2 r(1-\kappa)}{g}\ddot{z}tan\zeta cos\theta \quad . \quad . \quad . \quad . \quad . \quad (91)$$

The force given in equation (85) produces reactions from the guide and crank pin, the latter being found by taking moments about E, to be

$$= -\frac{R\omega^2\ddot{y}}{g} \times \frac{d}{l} = -\frac{R\omega^2\kappa}{g}\ddot{y}$$

and the moment produced by this force

$$= -\frac{R\omega^2\kappa}{g}\ddot{y} \times rcos\theta = -\frac{R\omega^2 r\kappa}{g}\ddot{y}cos\theta \quad . \quad . \quad . \quad (92)$$

Still neglecting the modification of the force system introduced by friction, the couple given in equation (86) will consist of two forces normal to AB, one at E and one at F. That is, the total forces on the guide and crank pin from steam and the inertia of the parts moving with E, and also that due to the movement of the center of gravity of the connecting rod considered in (a) and (b), will be modified to the extent of the forces which produce the angular motion of the rod. We may thus calculate these forces as if the couple alone existed.

The arm of this couple is $lcos\zeta$, and the force on the crank pin is

$$-\frac{I\omega^2}{g}\ddot{\zeta} \times \frac{1}{lcos\zeta} = -\frac{aI\omega^2\ddot{\zeta}}{grcos\zeta},$$

that on the guide being equal but of opposite sign. The turning moment due to this is

$$-\frac{aI\omega^2\ddot{\zeta}}{grcos\zeta} \times rcos\theta = -\frac{aI\omega^2}{g} \cdot \frac{\ddot{\zeta}cos\theta}{cos\zeta} \quad . \quad . \quad . \quad (93)$$

The whole turning moment due to the connecting rod is the sum of the separate moments given in equations (89), (91), (92), and (93). Analyzing these expressions in a similar manner to the previous ones we get,—

Turning moment due to connecting rod

$$= + \frac{R\omega^2 r^2}{g}(1-\kappa)\left\{ sin\theta \times \left(\frac{1}{4}a + \frac{1}{16}a^3\right) - sin2\theta \times \frac{1}{2}(1+\kappa) \right.$$
$$- sin3\theta \times \left(\frac{3}{4}a + \frac{9}{32}a^3\right) - sin4\theta \times \frac{1}{4}a^2(1-\kappa)$$
$$\left. + sin5\theta \times \frac{5}{32}a^3 + \right\} + \frac{a^2 I\omega^2}{2g} sin2\theta \quad . \quad . \quad . \quad (94)$$

This expression is only carried as far as a^3, though there is no difficulty in carrying it as far as desired.

It will be noticed that when $I = 0$ and $\kappa = 0$, the turning moment expressed by equation (94) reduces, as it should, to that we have previously found for a mass moving with the crosshead E.

Take $a = .25$. In a large number of cases we have very approximately $\kappa = .6$ and $I = R \times 1.6^2 r^2$. Equation (94) then becomes,—

Turning moment =

$$\frac{R\omega^2 r^2}{g}(.0254sin\theta - .2400sin2\theta - .0768sin3\theta$$
$$- .0025sin4\theta + .0010sin5\theta +). \quad . \quad . \quad . \quad (95)$$

Comparing equations (80) and (95) we see that the turning moment given by the latter is about half the former per unit mass. It is on this result that the statement at the top of page 45, Vol. IX, is based.

The functions giving the influence of the connecting rod can, of course, be treated graphically in the same manner as was done with equation (80).

This appendix consists almost wholly of the earlier portion of a paper about to be published by "Engineering."

Appendix F.

Further Note on the Composition of Tension and Shearing Stress at a Point.

Since the publication of the first part of this paper, Mr. H. C. Flood has drawn my attention to the formula given in many German text-books for calculating the strength of a circular bar

under combined crossbending and torsional loads. The equivalent bending moment being B_e we have, instead of equation (7),

$$B_e = \frac{5}{8}\sqrt{(B^2 + T^2)} + \frac{3}{8}B. \quad . \quad . \quad . \quad . \quad (96)$$

This is deduced from Poncelet's theory that the maximum *extension*, not the maximum stress, must be less than a definite quantity, to avoid rupture.* The formulas flowing from this theory seem to have gained complete acceptance on the continent of Europe, but are much less generally known and little used by English-speaking engineers.

The formula, equation (96), is quoted but not used by Prof. Unwin in his text book on Machine Design. Prof. Cotterill makes a very guarded reference to the theory, but does not regard it as proved.† Equation (96) will be found extensively applied in Mr. Suplee's translation of Prof. Realeaux's Constructor. So far as I know, though I have made no complete search, the deduction of equation (96) is given in English only in Prof. Lanza's Applied Mechanics.‡ Prof. Lanza also very strongly remarks on the want of experimental investigation of the strength of a shaft under combined torsion and bending.

To facilitate the discussion of the crank shaft problem I will give a simple deduction of the formula.

As in Fig. I, let P be the tension in pounds per square inch parallel to Ax, and U the shearing stress in pounds per square inch along all faces parallel to AB.

Take AB as the axis of y.

Put, again, E for Young's modulus, μ for the rigidity modulus and σ for the ratio of lateral contraction to longitudinal extension.

Take a point $C(x, y)$ in the unstrained solid, very near A, and

---

* See [§57]; also Todhunter and Pearson's History of the Theory of Elasticity, Vol. I, Art. 995. From numerous passages in this history, Prof. Pearson seems to accept Poncelet's theory absolutely.

† See Cotterill's Applied Mechanics, 1884, p. 426, and note p. 575. I have had no opportunity of consulting a later edition of this work.

‡ Page 690. New York: John Wiley & Sons.

let us measure its displacement due to the stresses P and U, the axes Ax, Ay being fixed in the solid.

Applying the pull P will shift the particle at C to C' (x', y') determined by the equations

$$\frac{Px}{x'-x} = E, \quad \frac{y'-y}{y} = -\sigma\frac{x'-x}{x};$$

or

$$x'-x = \frac{Px}{E}, \quad y'-y = -\frac{P\sigma}{E}y \quad . \quad . \quad . \quad . \quad (97)$$

Now applying the shearing stress U in the direction shown in Fig. I will cause a further shift of the particle originally at C to $C''(x'', y'')$. This point will be nearer the x axis than C' and is determined by,

$$x''=x', \quad \frac{Ux}{y'-y''} = \mu \quad . \quad . \quad . \quad . \quad . \quad (98)$$

The first of equations (97) and (98) give

$$x'' - x = \frac{Px}{E}.$$

The second give

$$y'' - y' = -\frac{Ux}{\mu},$$

$$y' - y = -\frac{P\sigma}{E}y.$$

Hence, by addition,

$$y'' - y = -\frac{Ux}{\mu} - \frac{P\sigma}{E}y.$$

We have for the resolved part of the length CC'' in the direction AC

$$\frac{(x''-x)\,x}{r} + \frac{(y''-y)\,y}{r},$$

where $AC = r$.

And as CC''/AC is very small, this gives for the strain of AC,

$$\varepsilon = \frac{(x''-x)\,x}{r^2} + \frac{(y''-y)\,y}{r^2}$$

$$= \frac{Px^2}{Er^2} - \frac{Uxy}{\mu r^2} - \frac{P\sigma y^2}{Er^2}. \quad . \quad . \quad . \quad . \quad . \quad (99)$$

As the angle $CAD = \psi$, equation (99) reduces to

$$\varepsilon = \frac{P}{E}cos^2\psi - \frac{U}{\mu}sin\psi cos\psi - \frac{P\sigma}{E}sin^2\psi$$

$$= \frac{P}{2E}(1-\sigma) + \frac{P(1+\sigma)}{2E}cos2\psi - \frac{U}{2\mu}sin2\psi. \quad . \quad (100)$$

Hence

$$\frac{d\varepsilon}{d\psi} = -\frac{P(1+\sigma)}{E}sin2\psi - \frac{U}{\mu}cos2\psi. \quad . \quad . \quad . \quad (101)$$

From equation (101) we find that the strain will be a maximum when

$$tan2\psi = -\frac{UE}{P\mu(1+\sigma)}. \quad . \quad . \quad . \quad . \quad . \quad (102)$$

As in Appendix B,

$$E/\mu = 2(1+\sigma). \quad . \quad . \quad . \quad . \quad . \quad . \quad (103)$$

This reduces equation (102) to,

$$tan2\psi = -\frac{2U}{P}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (104)$$

Equations (4) and (104) give the same pair of rectangular axes. Thus, for this case, the axes of principal tension and principal extension coincide. This can be so readily shown to be true in every case for an isotropic solid that the preceding investigation might have been omitted. But, the coincidence of these axes being otherwise obvious, we have in the above a proof of equation (103). This most important stress-strain relation was merely stated in Appendix B.

As P and U are figured, the value of ψ for the axis of principal extension is evidently negative and less than 45° if U and P are finite. Hence, from equation (104),

$$cos2\psi = \frac{P}{\sqrt{(P^2+4U^2)}}, \quad sin2\psi = -\frac{2U}{\sqrt{(P^2+4U^2)}}.$$

Putting these values in equation (100) and using equation (103) we get,

$$P_e = E\varepsilon = \frac{1+\sigma}{2}\sqrt{(P^2+4U^2)} + \frac{1-\sigma}{2}P, \quad . \quad . \quad . \quad (105)$$

where P_e is the simple longitudinal pull which would produce the same extension as the maximum due to U and P combined.

As on page 675, Volume VIII,

$$B = \frac{\pi}{32} P a^3 \text{ and } T = \frac{\pi}{16} U a^3,$$

where B and T are the bending and turning moments which would produce the stresses P and U respectively, in a circular bar of diameter a. Thus, we get from equation (105),

$$B_e = \frac{\pi}{32} P_e a^3 = \frac{1+\sigma}{2} \sqrt{(B^2 + T^2)} + \frac{1-\sigma}{2} B. \quad . \quad . \quad (106)$$

For $\sigma = .25$, equation (106) becomes,

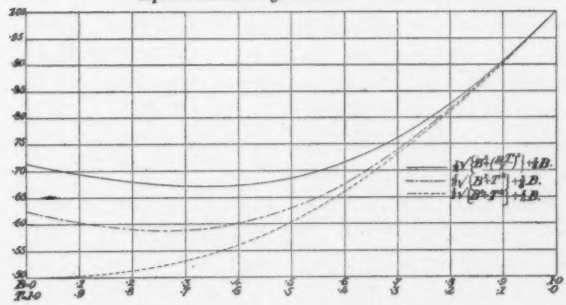
$$B_e = \frac{5}{8} \sqrt{(B^2 + T^2)} + \frac{3}{8} B,$$

which is the same as equation (96).

These formulas for the maximum stress involving a radical are due to Saint-Venant.*

Fig. XXXVI.

Comparison of Equations for Equivalent Bending Moments.



To compare the equivalent *bending* moments given by equations (7), (8) and (96) the curves in Fig. XXXVI were calculated.

* Todhunter and Pearson's History, Vol. I, Art. 1571.

They are plotted on a base for which $B + T = 1$, and include all values of the ratio B/T. The three curves necessarily coincide for $B = 1$ and $T = 0$.

The dotted curve, which assumes a definite maximum stress as the criterion of rupture, gives the lowest value of the equivalent bending moment for all finite values of T. The formula from which the curve is drawn I discarded years ago, it being so discordant with experiment as to be dangerous when torsion produced a large proportion of the stress. To obtain a rule agreeing better with experiment an artifice such as that in equation (8) was adopted, though no invariable ratio of augmentation of the turning moments or shearing stress was fixed on till the present investigation was commenced.

The dot-and-dash line curve is from Saint-Venant's formula, the two suppositions on which it is founded being that Poncelet's theory of rupture is true and that $\sigma = .25$. Saint-Venant was the greatest supporter of the school of elasticians who believed this to be the necessary value of σ for truly isotropic elastic bodies; but this conclusion is opposed by such eminent scientists as Prof. Stokes and Lord Kelvin, besides many other elasticians. The question has been carefully discussed by experimenters and the results seem strongly to uphold the latter authorities.*

With great deference I submit we must conclude either that one or both of the assumptions in Saint-Venant's formula are not strictly true, or that there are large experimental errors in many of the published experiments on torsion. It seems improbable that want of isotropy in the comparatively small test pieces turned down from larger forgings could have very much effect on the relative results.

The full line curve is drawn from the tentative equation (8). For most qualities of soft steel it probably errs a little on the safe side when the ratio T/B is large.

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* See, besides the references in Appendix B, the Historical Introduction in Mr. Love's Treatise, Vol. I, p. 14. Also see Todhunter and Pearson's History, Vol. I, Art. 921; Vol. II, Part I, Art. 192.

TABLE XXXIII.—ORDINATES OF CURVES IN FIG. VIII AND ARMS FOR BENDING MOMENTS—STEAM STRESSES ALONE.

TABLE XXXIII.—ORDINATES OF CURVES IN FIG. VIII AND ARMS FOR BENDING MOMENTS—STEAM STRESSES ALONE.

F_m.		10	20	30	40	50	60	70	80	90	100
Main journal diameter	A	.181	.230	.264	.292	.316	.337	.356	.373	.389	.404
	B	.173	.224	...	.292	...	.344	...	.387	...	.426
Main bearing length	A	.132	.208	.271	.327	.378	.425	.470	.512	.552	.590
Crank pin diameter	A	.176	.225	.262	.292	.317	.341	.362	.381	.400	.417
	B	.172	.222	...	.290	...	.341	...	.384	...	.422
Crank pin length	A	.128	.200	.258	.309	.354	.396	.435	.472	.506	.539
Crank web breadth	A	.193	.248	.288	.321	.349	.375	.398	.420	.440	.459
	B	.186	.244	...	.325	...	.387	...	.439	...	.486
Crank web thickness	A	.133	.169	.195	.215	.233	.249	.263	.276	.288	.299
	B	.128	.166	...	.218	...	.257	...	.289	...	.317
Span of main bearings, center to center	A	.544	.769	.945	1.096	1.231	1.353	1.467	1.573	1.673	1.768
	B	.534	.763	...	1.102	...	1.369	...	1.599	...	1.804
Clear distance between bearings	A	.412	.561	.674	.769	.853	.928	.997	1.061	1.121	1.178
	B	.402	.555	...	.775	...	.944	...	1.087	...	1.214
Arms for bending moments.* h	A	.075	.115	.149	.178	.205	.229	.253	.274	.295	.315
k	A	.141	.200	.246	.286	.321	.354	.384	.412	.439	.465
H	A	.469	.654	.796	.918	1.026	1.124	1.214	1.299	1.378	1.453
K	A	.403	.569	.699	.810	.910	.999	1.083	1.161	1.234	1.303
H_1	A	.197	.269	.324	.370	.411	.447	.481	.512	.541	.569
K_1	A	.131	.184	.226	.262	.294	.323	.349	.374	.397	.419

Dimensions are in inches per one inch stroke of engine.
A. All bearings in line—full lines Fig. VIII.
B. Bearing *B* removed and the other bearings in line—dotted lines Fig. VIII.
* The arms for the bending moments are indicated by the same letters as in Fig. IV.

Appendix G.

Tables XXXIII and XXXIV give the calculated ordinates of the curves in Figs. VIII, and XIV to XXI; also the numerical values of the arms for the bending moments. They were calculated to four decimals to assist the prediction of the succeeding values in the trial and error calculations. The fourth decimal has however been cut off as it was not always perfectly correct and is of no practical importance. These tables will be useful to any one studying the subject of the preceding paper.

TABLE XXXIV.—ORDINATES OF CURVES IN FIGS. XIV TO XXI AND ARMS FOR BENDING MOMENTS—STEAM AND INERTIA STRESSES.

$B = 0$.

F_m.		10	20	30	40	50	60	70	80	90	100
Main journal diameter		.157	.198	.227	.250	.270	.287	.302	.316	.329	.341
Main bearing length		.047	.074	.097	.118	.137	.154	.171	.186	.202	.216
Crank pin diameter		.149	.189	.217	.240	.260	.277	.293	.307	.320	.332
Crank pin length		.053	.083	.108	.131	.151	.170	.188	.205	.221	.236
Crank web breadth		.164	.208	.239	.264	.286	.305	.322	.337	.352	.365
Crank web thickness		.115	.145	.167	.184	.199	.211	.223	.233	.243	.252
Span of main bearings, center to center		.346	.467	.563	.642	.712	.776	.834	.889	.942	.991
Clear distance between bearings		.299	.393	.466	.524	.575	.622	.663	.703	.740	.775
Arms for bending moments.*	h	.031	.047	.060	.071	.082	.091	.100	.109	.117	.125
	k	.089	.119	.144	.164	.181	.197	.212	.226	.239	.251
	H	.315	.420	.503	.571	.630	.685	.734	.780	.825	.866
	K	.257	.348	.419	.478	.531	.579	.622	.663	.703	.740
	H_1	.142	.186	.221	.250	.274	.296	.317	.335	.354	.370
	K_1	.084	.114	.138	.158	.175	.191	.205	.219	.232	.244
Main journal diameter		.165	.209	.240	.265	.286	.305	.322	.337	.351	.365
Main bearing length		.083	.131	.171	.207	.239	.269	.298	.325	.351	.375
Crank pin diameter		.157	.201	.233	.259	.282	.302	.320	.337	.353	.368
Crank pin length		.100	.156	.202	.242	.278	.312	.343	.372	.400	.427
Crank web breadth		.178	.233	.275	.310	.340	.367	.392	.415	.437	.458

$m = 2$.	Crank web breadth	.173	.222	.257	.285	.310	.332	.352	.371	.388	.405
	Crank web thickness	.123	.156	.179	.198	.214	.228	.240	.252	.262	.272
	Span of main bearings, center to center	.446	.620	.756	.871	.973	1.067	1.153	1.234	1.310	1.382
	Clear distance between bearings	.363	.489	.585	.664	.734	.798	.855	909	.959	1.007
	Arms for bending moments.* h	.050	.076	.098	.117	.134	.150	.165	.179	.193	.306
	Arms for bending moments.* k	.111	.154	.187	.216	.241	.264	.285	.305	.324	.342
	Arms for bending moments.* H	.396	.544	.658	.754	.839	.917	.988	1.055	1.117	1.176
	Arms for bending moments.* K	.335	.466	.569	.655	.732	.803	.868	.929	.986	1.040
	Arms for bending moments.* H_1	.173	.234	.280	.319	.353	.384	.412	.438	.462	.485
	Arms for bending moments.* K_1	.112	.156	.191	.220	.246	.270	.292	.312	.331	.349
$m = 3$.	Main journal diameter	.177	.225	.259	.287	.311	.332	.351	.369	.385	.401
	Main bearing length	.131	.206	.267	.322	.371	.417	.460	.501	.539	.576
	Crank pin diameter	.171	.222	.260	.291	.319	.344	.367	.388	.408	.427
	Crank pin length	.160	.247	.317	.376	.430	.478	.523	.565	.604	.641
	Crank web breadth	.188	.244	285	.320	.351	.378	.404	.427	.449	.470
	Crank web thickness	.134	.169	.194	.215	.232	.248	.262	.274	.286	.298
	Span of main bearings, center to center	.576	.814	.999	1.157	1.297	1.425	1.542	1.651	1.755	1.853
	Clear distance between bearings	.445	.608	.732	.835	.926	1.008	1.082	1.150	1.216	1.277
	Arms for bending moments.* h	.074	.114	.147	.175	.201	.225	248	.269	.289	.308
	Arms for bending moments.* k	.141	.199	.244	.283	.317	.349	.379	.406	.432	.457
	Arms for bending moments.* H	.502	.700	.852	.982	1.096	1.200	1.294	1.382	1.466	1.545
	Arms for bending moments.* K	.435	.615	.755	.874	.980	1.076	1.163	1.245	1.323	1.396

$\mathfrak{M} = 5$.	Main bearing length	.131	.206	.267	.322	.371	.417	.460	.501	.539	.576
	Crank pin diameter	.171	.222	.260	.291	.319	.344	.367	.388	.408	.427
	Crank pin length	.160	.247	.317	.376	.430	.478	.523	.565	.604	.641
	Crank web breadth	.188	.244	.285	.320	.351	.378	.404	.427	.449	.470
	Crank web thickness	.134	.169	.194	.215	.232	.248	.262	.274	.286	.298
	Span of main bearings, center to center	.576	.814	.999	1.157	1.297	1.425	1.542	1.651	1.755	1.853
	Clear distance between bearings	.445	.608	.732	.835	.926	1.008	1.082	1.150	1.216	1.277
	Arms for bending moments.* h	.074	.114	.147	.175	.201	.225	248	.269	.289	.308
	k	.141	.199	.244	.283	.317	.349	.379	.406	.432	.457
	H	.502	.700	.852	.982	1.096	1.200	1.294	1.382	1.466	1.545
	K	.435	.615	.755	.874	.980	1.076	1.163	1.245	1.323	1.396
	H_1	.214	.293	.353	.403	.447	.487	.523	.557	.588	.618
	K_1	.147	.208	.256	.296	.331	.363	.392	.420	.445	.469
$\mathfrak{M} = 8$.	Main journal diameter	.188	.240	.277	.308	.335	.359	.380	.400	.419	.437
	Main bearing length	.174	.272	.352	.423	.487	.545	.600	.651	.700	.746
	Crank pin diameter	.184	.242	.287	.324	.357	.387	.414	.440	.464	.487
	Crank pin length	.213	.323	.410	.483	.548	.607	.661	.712	.759	.803
	Crank web breadth	.202	.266	.315	.356	.392	.425	.455	.484	.510	.536
	Crank web thickness	.142	.180	.208	.230	.249	.266	.282	.297	.310	.323
	Span of main bearings, center to center	.690	.979	1.205	1.397	1.567	1.721	1.864	1.996	2.121	2.239
	Clear distance between bearings	.516	.707	.853	.974	1.080	1.176	1.264	1.345	1.421	1.493
	h	.096	.148	.190	.227	.260	.291	.319	.346	.371	.395

Arms for bending moments.*	B	.096	.148	.130	.227	.260	.291	.319	.346	.371	.395
	b	.167	.238	.294	.342	.385	.424	.460	.494	.526	.556
	H	.594	.831	1.015	1.170	1.307	1.430	1.545	1.650	1.750	1.844
	K	.523	.741	.911	1.055	1.182	1.297	1.404	1.502	1.595	1.683
	H_1	.249	.342	.413	.471	.523	.569	.613	.652	.689	.724
	K_1	.178	.252	.309	.356	.399	.436	.472	.504	.534	.563
Main journal diameter		.195	.249	.289	.322	.350	.376	.399	.421	.441	.460
Main bearing length		.200	.312	.403	.483	.555	.621	.682	.739	.794	.845
Crank pin diameter		.193	.256	.304	.345	.381	.414	.445	.473	.500	.525
Crank pin length		.243	.367	.463	.544	.615	.680	.739	.794	.846	.894
Crank web breadth		.212	.282	.335	.380	.420	.456	.489	.520	.550	.577
Crank web thickness		.147	.187	.216	.240	.260	.278	.295	.311	.325	.339
Span of main bearings, center to center		.757	1.078	1.327	1.539	1.726	1.895	2.051	2.196	2.334	2.464
Clear distance between bearings		.557	.766	.924	1.056	1.171	1.274	1.369	1.457	1.540	1.619
Arms for bending moments.*	h	.110	.169	.216	.258	.295	.329	.361	.390	.419	.446
	k	.183	.262	.324	.378	.425	.468	.508	.546	.582	.615
	H	.647	.909	1.111	1.281	1.431	1.566	1.690	1.806	1.915	2.018
	K	.574	.816	1.003	1.161	1.301	1.427	1.543	1.650	1.752	1.849
	H_1	.269	.370	.448	.512	.568	.618	.665	.708	.748	.786
	K_1	.196	.277	.340	.392	.438	.479	.517	.552	.585	.617

$\frac{B}{D} = 10.$

Dimensions are in inches per one inch stroke of engine.
* The arms for the bending moments are indicated by the same letters as in Fig. IV.

RECONSTRUCTED AMERICAN MONITORS.

By Passed Assistant Engineer F. M. Bennett, U. S. Navy.

In the mechanical world the monitor is an excellent example of the survival of the fittest. Its prototype was rude and uncouth, like the primitive man, with little seeming chance in the struggle for life with previously existing forms, but, like man, it has overcome its enemies and bettered its first condition to such an extent that it now occupies a dominant position in its peculiar sphere. It is a far cry from Ericsson's *Monitor* to a modern battleship, yet the latter in all navies is the result of evolution from the former, and, when stripped of the scientific appliances not essential to its success, presents the features that comprised all there was of the *Monitor*. Originally a mailed, self-moved battery, it consisted only of armor, steam machinery and the gun, all rude, but harmoniously combined by a master engineer into a union capable of greater endurance, offensive and defensive, than was possessed by the huge fabrics that ruled the seas before it, and which disputed in vain its right to existence.

The battleship is a higher development than will be undertaken as the subject of this essay. We have in our rehabilitated Navy some fighting machines that occupy a middle place between the primitive monitor and the modern battleship, and, as the haps and mishaps of these vessels have attracted a certain amount of public attention during the past few years, it is thought that some account of them may be valuable to all interested in the application of steam machinery to naval warfare. Engineers especially should take an interest in this subject, for their profession is responsible for the creation of this type of warship and for its survival in spite of as stubborn and powerful an opposition as ever resisted a mechanical innovation.

The history of our modernized monitors is involved, but may

be interesting if briefly reviewed. While being built, Ericsson's *Monitor* was ridiculed by the press, and the project was stoutly opposed by naval officers who could not see in a mastless iron structure any characteristic of what they thought a war vessel should be. A clause of the contract, not carried out but which illustrates the belief of the time, required that the *Monitor* be fitted with masts and sails sufficient to propel her at the rate of six knots per hour in a fair wind without aid from the engines. Her performance in Hampton Roads reversed the tone of the press and partially quieted the naval conservatives. So completely was public opinion won that, under its pressure, the Navy Department proceeded at once with the construction of a veritable fleet of steam turret-batteries, mostly from Ericsson's plans, though, notably on the Western rivers, some designs of other engineers were adopted.

The largest iron clad of this fleet, which was also the largest monitor ever built, was contracted for with John Ericsson and was named by him *Protector*, but the Navy Department changed the name to *Puritan*. The original plan was for a single screw vessel of nearly 5,000 tons displacement, with one huge turret for two 20-inch guns. The Department compelled the adoption of two turrets and two screws, though Ericsson opposed these changes. His idea was one powerfully armed turret with all-around fire, and so firm was his faith in this arrangement that he wrote to Mr. Fox, Assistant Secretary of the Navy, in an argument against the change, that "The day is not far distant when two turrets on a vessel will be admitted to have the same advantages as two heads on the human body, or two suns in the heavens." It may be stated that, in carrying out the project for all-around fire, the original *Monitor* had no smoke pipe and that she fought the *Merrimac* without one. Her two boilers discharged their products of combustion into grated openings in the deck, around which short rectangular trunks were bolted to keep water out when at sea, but these were unshipped in action. There is no record that the smoke from these holes troubled the crew in the turret, though one would expect that result. On the voyage from New York to Hampton Roads the short smoke

trunks were found inadequate in a sea-way, and the vessel was nearly lost because of the quantity of water taken in by them. Though dispensing with the smoke pipe, it is a curious fact that Ericsson blocked his gun fire ahead by building an armored pilot house on the forward deck of the *Monitor;* this proved such an embarrassment that the pilot house was put on top of the turret in subsequent monitors.*

The *Puritan* was launched in July, 1864, two years after her construction had been undertaken by the Continental Iron Works, Greenpoint. Her machinery was built by the Allaire Works, New York. The end of the war found her unfinished and work was stopped, for the policy then was to reduce the fleet, not to increase it. Ten years later, under the cloak of "repairs," the building of a new *Puritan* around the old name was undertaken, and arrangements were made with Mr. John Roach, of Chester, Penna., to that end. The original *Puritan* was handed over to Mr. Roach at a valuation of about $43,000 and broken up for the material, some of which is said to have been used in the new vessel. The new *Puritan* also absorbed the light draught monitors *Cohoes*, *Casco*, *Chimo*, *Modoc*, *Napa*, *Nausett* and *Waxsaw*, all bartered to Mr. Roach. A change of administration put a stop to construction work on the *Puritan*. The new *Puritan*, which is much larger than the old one, lay idle for ten years more until Congress voted money for her completion as one of the steps in the creation of a new navy. The work of completion was undertaken at the New York Navy Yard, and proceeded so leisurely that yet another decade passed by before she was ready for service. The hull is of iron, and is as heavy and staunch as can be desired. The four 12-inch guns, mounted in two barbette turrets, are modern and have modern mounts, but the armor is light. The machinery presents one of the earliest examples of compound practice in this country, and is interesting chiefly as an object for antiquarian investigation.

* Mr. W. C. Church says, in his "Life of John Ericsson," that this arrangement was designed by Ericsson before the *Monitor* was built. Professor J. Russell Soley, in "The Blockade and the Cruisers," says it was suggested by Mr. Isaac Newton, the first engineer of the *Monitor*, immediately after the conflict with the *Merrimac*.

In the same year, (1862,) that the *Puritan* was begun, four large double-turreted monitors were put under construction at navy yards, and machinery for them contracted for with engine builders in New York and Philadelphia. The hulls were of wood, armored above water and on deck. As there were then no appliances at any navy yard for working heavy masses of iron, the turrets, side armor, etc., were obtained by contract with various iron manufacturers. These vessels were the *Agamenticus* (name changed to *Terror* in 1869), built at the navy yard in Kittery, Maine; *Miantonomoh*, built at New York; *Monadnock*, built at Boston; and *Tonawanda* (changed to *Amphitrite* in 1869), built at Philadelphia. All were completed within a reasonable time and all saw some service. The *Monadnock* fought at Fort Fisher and a year later astonished the deriders of monitors by steaming from Philadelphia to San Francisco, by way of Magellan's straits, without any assistance whatever. The *Miantonomoh* crossed the Atlantic ocean in 1866 and visited several European ports and dockyards, to the surprise and chagrin of the British press, which had long maintained that monitors could not go to sea and had ridiculed the idea of one of them ever appearing in English waters.

The subsequent histories of these ships were not unlike that above outlined in the case of the *Puritan*. The system of "repairing" was applied to them, and new iron ships, larger than the old ones, were built as follows: *Monadnock* by Phineas Burgess, Vallejo, Cal.; *Terror* by the Cramp Co. of Philadelphia; *Amphitrite* by Harlan and Hollingsworth, Wilmington, Delaware; and *Miantonomoh* by John Roach, Chester, Pa. Like the *Puritan*, all were unfinished and lay neglected for many years, until at last taken to navy yards and completed by such slow stages that ten years were added to their ages. The *Monadnock* went to the Mare Island Navy Yard, where modern triple expansion engines and high pressure boilers were provided. Machinery for the others, unfortunately, was completed by the original contractors, and it has consequently been retained in such condition as neglect and the ravages of time have allowed. They have twin screws actuated by heavy, but feeble, compound engines

of an early type, placed opposite each other and inclined about 30 degrees, with the shaft of each engine under the cylinders of the other and the connections interlacing in a manner admirable for compactness, but exceedingly provoking and inaccessible for purposes of cleaning and repairing.

It is not thought necessary to include in this paper any tables of data or statements of dimensions of these monitors and their machinery. Such information is in print in various publications, notably the annual reports of the Bureau of Construction and Repair, and is within reach of all who have interest in it.

Ericsson conceived the monitor type as vessels for coast and harbor defense only. He described his invention as a raft for carrying a fort, and he had no expectation of its being used as a cruiser or going to sea at all except to transport its fort along the coast to the point to be defended. The performances of the first *Miantonomoh* and *Monadnock* were valuable, because they proved the sea-worthiness of the type and stopped a great amount of carping, but this was achieved at great price of human labor and suffering and should not be imitated, even by the improved monitors, except under the spur of actual military necessity. Full confidence in the sea-worthiness of monitors does not exist yet, in spite of their records. When the North Atlantic squadron was caught in the great storm off Cape Hatteras last February, the *Amphitrite* was compelled to heave to by the really appalling masses of water that boarded her, and thus was lost sight of by the other ships during a very wild night. Her absence caused such anxiety that, when day broke, the *New York*, *Maine* and *Columbia* were dispersed over that part of the ocean seeking for her, and her ultimate discovery in an undamaged condition, jogging along toward the point of destination, was a source of relief and joy. Except for a whale boat crushed by a sea, she passed through the ordeal practically uninjured, though men were lost from both the *Maine* and *Marblehead* and both those ships suffered serious damage. The *Amphitrite* was not a pleasant home during that period, however.

The *Amphitrite* has now been in commission over two years and, as she has attempted to do the duty of a cruiser, she has had

more active service than any other vessel of the type and has afforded a better opportunity for observing and correcting original faults. As a typical example, it is believed a narrative of personal experience on this vessel in efforts to overcome defects, both inherent and due to age, will be interesting and instructive to the profession. After experiencing the vicissitudes in building above outlined and having reached the condition of a strongly built iron tank, shaped somewhat like a ship, with propelling machinery installed on board, the *Amphitrite* was taken to the Norfolk Navy Yard to be completed. This work involved the installation of turrets and guns, auxiliary machinery, ventilating systems, side armor, decks, interior fittings, etc., in complete detail, and afforded a fine field for making a handy and habitable fighting machine. Perhaps the building at the same yard at the same time of the foreign-born battleship *Texas* robbed the *Amphitrite* of the attention necessary to compass this end; at any rate, it was not realized until several months of severe labor in various directions and not a little personal discomfort had been undergone by the officers and men first attached to the vessel for sea service.

The *Amphitrite* was put into commission on April 23, 1895. Stores, ammunition and equipment were put on board, the perfunctory and inadequate dock trial was observed, and on May 9, sixteen days after going into commission, she got under way and steamed slowly to an anchorage inside of Cape Henry. A navy yard tug, in readiness to render aid in case of breakdown, accompanied us as far as Fortress Monroe and a number of navy yard mechanics were on board to that point. The next morning we got under way and very soon encountered a defect in organization that put the ship in real peril and made the immediate hauling of all fires necessary, because of ignorance in the fire room.

The supplying of water to a boiler under steam is an important matter; so vital in fact that, on shore, laws and licenses generally prohibit inexperienced persons from endangering the neighborhood by attempting to do it, though the explosion of boilers in saw mills and on farms is frequent enough to keep the

reading public informed of the natural result of incompetence in this regard. When a number of steam boilers is cramped into a dark and limited space on shipboard, and the problem is further complicated by the use of salt water and the uncertainty of water level due to rolling, the service becomes so serious that nerve, knowledge and experience are requisite on the part of the water tenders to protect the ship and its crew from sudden destruction. Under no circumstances can a boiler explosion have such frightful possibilities as at sea, and for this reason the greatest precautions should be taken to ensure vigilant and capable boiler attendants for ship service.

In apportioning a crew for the *Amphitrite*, the engineers' force was reduced by dispensing with water tenders, the blacksmith, boiler maker and coppersmith being ordered to assume their duties; this perhaps on the supposition that a mechanic is an interchangeable being without specialty in trade. The fact is, however, that the trades mentioned, even that of boiler making, have no earthly connection with the management of boilers, and artisans representing them are no more to be expected to know how to control boilers under pressure than coopers, clock makers or molders might be. The defect was not developed by the few hours' steaming from Norfolk, with navy yard men and the greater part of the regular force in the engine and fire rooms to assist at the first working of the machinery under way, but it appeared at once when our force went into regular sea watches. A trivial cause (hot feed water) interfered with the action of the main feed pump, and as this was not remedied or other pumps put in use by the "water tender," who happened to be the boiler maker, the water in the boilers gradually disappeared without exciting his interest.

Information of the trouble eventually reached the engine room through the medium of scared firemen, who knew the situation to be abnormal and dangerous. Hasty investigation developed the startling fact that the boiler maker had not been giving the slightest heed to the feed pump, and actually did not know that water should be kept up to a certain level in the boilers; equally startling was the conflicting testimony of men in the fire room,

who differed from ten minutes to one hour in their estimates of the time when water had last been seen in the gauge glasses. Men from the watches off duty were summoned and all fires hurriedly hauled, perhaps not a moment too soon; pressure was then reduced, tube sheets examined, water pumped up in the boilers, and fires started again after a loss of about two hours. The three official water tenders were forthwith removed from duty and their places filled by old firemen, who, though sorely spared from the fires where they belonged, knew something about tending water. Discipline was somewhat perverted by putting the mechanics on watch for instruction under these firemen, their juniors in the military classification of enlisted men. Two of these three mechanics had never been to sea before and became useless from seasickness, besides being utterly ignorant of water-tending. After several months' experience they became habituated to sea life and learned to manage the boilers satisfactorily. During those months, instead of adding to the working force, they actually reduced it by the three firemen diverted from their proper labors.

The ship proceeded at once to Savannah, a distance of nearly 500 miles, at such a moderate rate that ninety-eight hours elapsed from port to port; complete cessation of progress was avoided on the last two days only by the liberal use of streams from the fire hose on the crank pins. This is probably the first instance of an untried monitor being sent, without convoy, on a long sea voyage in the season when bad weather is to be expected; it is certainly very unusual for any naval vessel to take the sea so soon after going into commission. A number of faults were developed about the machinery, particularly in the matter of bulkhead and other steam joints, which were so old that many gave way under prolonged use. The crank pins and main journals were subsequently found badly fitted, probably by galvanic action during the years that the engines lay idle. Owing to the short time the ship had been in commission, the men were not very familiar with the machinery and pipe connections, and this, added to the defects that developed and the discomfort caused by rough weather, made the trip a trying one, particularly for

the chief engineer and his one assistant, who alternated in four-hour watches the whole time.

The defects in machinery that appeared were, as has been said, due to age and neglect, though the latter perhaps is too harsh a word when we reflect that scanty appropriations practically prevent navy yard officials from preserving vessels in ordinary. The dock trial required after a ship is commissioned is intended as a means of discovering faults, but it is conducted in such manner as to be inadequate. I have taken part in dock trials of many vessels and in every case orders have been issued limiting the power exerted, in order that the dock be not injured by the strain of the hawsers or undermined by the wash of the propellers. Result is that only part of the boiler power is used and generally at low pressure; the engine speed is slow and usually limited to one engine at a time, while the duration of the trial is brief, because it interferes with the work of getting stores and equipping the ship. Instead of bringing the weak points into prominence, this practice is really a means of hiding them. This preliminary trial should be made in free route; should be of twelve hours' duration at least, and full power should be exerted part of the time. This might involve the loss of a day in fitting out, but would save many days of trouble and hard labor thereafter.

The first trip of the *Amphitrite*, with battle hatches and superstructure doors closed to keep the seas out, brought up the question of internal temperatures in a very painful manner. The temperature of the outside air varied with latitude and with day and night from 50 to 72 degrees, but, even with this cool atmosphere, the engine room ranged from 120 to 140, and the fire room from 140 to 160 degrees. This seemed severe and some of the men broke down under it, but events proved it to be only a mild foretaste of what was in store. After about three weeks on the southern coast we returned north, having bad weather again off Hatteras and going through the same chapter of discomforts experienced on the way down, except that the ship was hotter because the season was advancing.

At Hampton Roads, the Board of Inspection and Survey ex-

amined the vessel, and the full power steam trial required for that inspection brought more trouble. The day (June 25), was very hot and still, impairing the furnace draft, which was wretched at best, and imposing great discomfort upon the engineers' force because of heat below. On the working platform of the engine room, the thermometer ranged from 138 to 158 degrees during the afternoon watch when full power was attempted, the working gear being so hot that it could not be handled without gloves or hand rags. The fire room varied from 157 to 170 degrees. Under such conditions nothing like the maximum steam pressure could be maintained, and the full power effort resulted in a mean speed of 7.27 knots for less than two hours. When the call to general quarters sounded, the steam pressure was far below that required to produce the hydraulic power needed to work the turrets, and was obtained only by stopping the main engines, as described by the following extract from the steam log of that day.

* * * "Ahead full speed at 1·38. By this time it was found impossible to keep up steam on all six boilers at more than about 45–50 pounds with the force on watch and keep the main engines running at full speed. Eight members of the engineers' force are on the sick list; two men of this watch were overcome by the heat before 1 P. M. and put on sick list; all the firemen and coal passers of one watch and three of another are now in the turrets at gun stations for general quarters, leaving four firemen and four coal passers only to work all the furnaces in the ship. The steam pressure being insufficient to work the turret-turning mechanism, the state of affairs was reported to the commanding officer, and by signals from the bridge the main engines were stopped or run at slow speed for 25 minutes from 1·48, by which resort sufficient steam was raised to operate the turrets, and target practice was proceeded with."

The great gun firing was reported as very successful. Nevertheless, had the action been real instead of simulated, the delay of 25 minutes in getting up steam might, and probably would have been fatal. In this case, lack of men in the fire room was the direct cause of the guns being powerless for a period long enough to have permitted a much weaker foe to disable or

destroy us. The object in taking men from the fire room force to swell the gun divisions at drill is said to be to create a reserve force familiar with the working of guns, to draw upon to fill vacancies in battle. As a general proposition, it may be safely advanced. that the fireman will render the best service and contribute most to the fighting efficiency of his ship if he keeps up steam on the boilers. At best he gets small knowledge of gun drill. The firemen of the *Amphitrite* detailed for the turret crews were stationed in the magazines and handling rooms to get out ammunition, and were completely separated from the guns and exercises of the turrets. I frequently questioned these men as to their stations, and in a period of two years failed to find even one who had ever been stationed in a turret or given any instruction in the working of the guns; this, too, when they were accustomed to handling machinery and, therefore, especially qualified to readily learn the mechanical work of operating such guns. In many ships it is the practice to draw heavily upon the engineer division to increase the powder division. Men so detailed are as remote from the guns as though they remained in the fire room, and they gain no knowledge of the working of the battery.

The great internal heat that rendered the *Amphitrite* inefficient was due to lack of provision for ventilation in the engine and boiler spaces. These regions became so hot that little useful work could be done in them, and the lack of air was such as to actually ruin the furnace draft, smoke coming out freely from the holes in the furnace doors. Aside from two small ash hoist tubes in the central part of the fire room and a small escape hatch forward, there were no openings from the fire room to the outer air. One of the ash tubes was the mast and had a cap at the top; the other had a revolving cowl at the top just abaft the smoke pipe, and shut off from any beam winds by boats stowed on each side of it. The escape hatch opened under the bridge and was surrounded by the conning tower, the mast, hammock nettings and other deck fittings. Two blowers on the forward engine gallery drew air from an armored tube and discharged it into the fire room or into the engine room, or both ways, accord-

ing to the arrangement of the dampers, the latter being the usual practice. The very successful regenerative principle upon which this blower circuit was designed and constructed will be described further along.

The boilers reached nearly to the iron main deck of the vessel, and as the air above them and between the deck beams had no escape, it became greatly heated and lay roasting in those spaces. It was impossible for a man to go on the gratings behind the upper parts of the boilers after they had been under steam a few hours, though the main and auxiliary stop valves were there. A Board of officers that reported on temperatures in the vessel got at this place only by introducing a thermometer on the end of a long pole, and this thermometer, when fished out and taken to a place where it could be read, showed 202 degrees. The superstructure containing the cabin and ward room was directly above the engine and boiler rooms, with a light wooden floor laid over the iron main deck. At sea with the doors closed, this habitation became exactly like a frying pan on a hot stove lid. The smoke pipe, partly uncovered for alleged ventilating purposes, passed through the center of the ward room and by vigorous radiation contributed its full share to the general discomfort. The deck, in spite of its wooden sheathing, was so hot as to be painful, and I hesitate to say from memory the temperatures the Board reported as being usual in the rooms, in bureau drawers, on the ward room table and in other parts of the officers' quarters. It was as high as 112 degrees and I think greater. Sleep was only a period of unconsciousness, induced by utter exhaustion, and was without restful quality.

The state of affairs was reported by the Board of Inspection and by the commanding officer, but before any action was taken, we were suddenly ordered to go to Brunswick, Georgia, to drill a company of naval militia at that place. The trip of about 500 miles occupied five days in the latter part of July and, for sheer suffering, has perhaps seldom been equalled in our naval history. The fire room temperature was never below 150 degrees and often above 170, while the engine room ranged closely about 150 degrees. For the first twenty-four hours the men stood it well,

but on the second day, seven succumbed to the heat and were put on the sick list, one of them nearly dying; before the voyage was ended, twenty-eight had been driven to seek medical attendance. The gaps thus created were partially filled with inexperienced men from the deck force, until there was only a life boat's crew left in each watch. The water gauges were defective, being constructed on a scientific principle too delicate for use with supersalted or impure water. By choking with salt they caused anxiety and danger, because the quantity of water in the boilers could not be accurately known, and their light spring valves, becoming clogged open, added to the misery of the fire room by blowing steam and hot water constantly. The uncertainty about water in the boilers kept the men in a nervous state of mind bordering on panic, and caused the hauling of fires from one or more boilers time after time, thus augmenting the infernal heat of the fire room. Under such conditions no fair steam pressure could be maintained, and all this pitiful suffering and toil resulted in progress of barely five knots.

On the evening of the fourth day out our men had literally fought with fire to a finish and had been vanquished; the watch on duty broke down one by one and the engines, after lumbering along slower and slower, actually stopped for lack of steam. The ship was allowed to drift in shore on the tide and was finally brought to an anchor in St. Simon's sound. Though a warship of formidable characteristics and sent on this distant service, it is doubtful if the *Amphitrite* could have gone into action at that time, or have steamed one hundred miles further to save herself. The responsibility for this must be charged to the faults in her construction and not to her crew, who, officers and men alike, exerted themselves to the utmost under the most trying and discouraging circumstances.

At daybreak the next morning we got under way and steamed at a very conservative rate to our destination, fortunately only about ten miles distant. The scene in the fire room that morning was not of this earth, and far beyond description. The heat was almost destructive to life; steam was blowing from many defective joints and water columns; tools, ladders, doors and all fittings

were too hot to touch, and the place was dense with smoke escaping from furnace doors, for there was absolutely no draft. The men collected to build up the fires were the best of those remaining fit for duty, but they were worn out physically, were nervous, apprehensive and dispirited. Rough Irish firemen, who would stand in a fair fight until killed in their tracks, were crying like children and begging to be allowed to go on deck, so completely were they unnerved and unmanned by the cruel ordeal they had endured so long. "Hell afloat" is a nautical figure of speech often idly used, but then we saw it.

For a month thereafter the ship was actively employed on the southern coast, drilling naval militia at different ports and sweltering in the new dock at Port Royal. One trip of twenty-nine hours broke the record for heat, the fire room being frequently above 180 degrees. All fire room temperatures referred to in this paper were taken in the actual spaces where the men had to work, and not from hot corners or overhead pockets. We got back to Norfolk on the 23d of August, and though that place is notorious for heat at that season, it was a relief to us to get even that far north and let our overcharged engines and boilers radiate their heat at leisure. The ship had then been in commission four months, during which time the main boilers had been under steam forty-three days, and all our steaming had been south of the Capes of the Chesapeake during the hottest months of the year. With the exception of two days in the Port Royal dry dock, we had always had steam on one, and sometimes two boilers, for running auxiliary machinery and turrets.

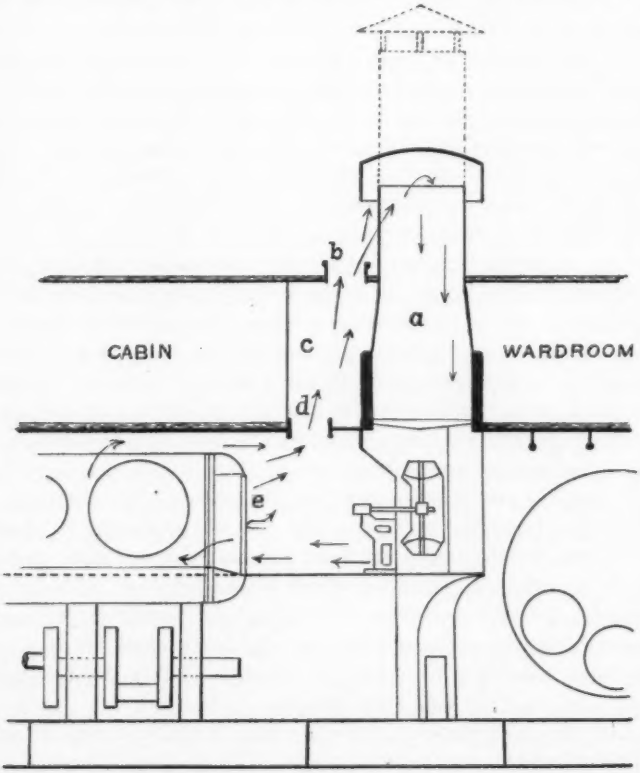
So much for actual experience in a reconstructed monitor. Let us now look at the means by which the worst faults were corrected without appealing to the higher mathematics or abstruse sciences. Two Boards, one composed of officers of the ship and the other of members of the Board of Inspection and Survey, reported upon conditions as they existed, and the Navy Department authorized the principal changes that had been recommended. Four large ventilators with revolving cowls were put through the protective deck into the fire room, one in each forward corner and the others over the two after boilers.

The ash hoist tube, formerly screened by the boats and smoke pipe, was built several feet higher and fitted with two branches, one on each side of the smoke pipe. The latter was boxed in where it passed through the ward room. Two ventilators were also let into the top of the engine room, a previously existing uptake pipe with a close-fitting mushroom cap being utilized as the trunk of one of these.

The immediate effect of these additions was remarkable. By admitting outside air to the oven-like spaces over the boilers, the fire room temperature was reduced to a living figure, and the ward room deck above it ceased to resemble the top of a stove. The same improvement resulted in the engine room. This method of ventilation is the only one that appears sensible from the standpoint of the ship, no matter how scientific may be the theory of pumping hot air out of internal spaces. It does the men who work in those spaces no good to know that hot air is going out, when they can feel that it is well baked before it goes. By mingling the heated air below with cold fresh air from above decks, the general temperature is lowered and the resulting mixture fit to breathe. Furthermore it will make fires burn, as the change in the *Amphitrite* showed in a striking manner. Instead of smouldering furnaces we had bright steam-making fires and, instead of painfully dragging along at four or five knots, our progress was increased from two to three knots, varying with the weather and state of the sea. A perfectly fair comparison was made possible, for, a year after our first trials on the southern coast, we steamed north from Key West in the latter part of June touching at the same ports we had visited the summer before. On this voyage the engine and fire room temperatures were thirty degrees less than the year before, and the speed of the ship, which had been lying five months at Key West without docking, was fully two knots greater.

Another important change was made in the source of supply of air for the engine room blowers. The regenerative feature of the original arrangement has already been mentioned and may best be described by reference to the accompanying sketch, copied from a blue print showing the change that was made.

The large air downtake *a*, armored for four feet above the main deck, is located amidships between the engine and fire rooms, and originally extended about four feet above the superstructure deck. Two blowers on the engine room grating draw air from the tube and discharge it into the engine room or into the fire room, or both. The top of the tube was capped as shown, the lower rim of the cap being about three feet above the hatch *b*.



A small enclosed trunk *c*, in which there is a ladder, affords escape from the engine room through the hatch *d*. In operation, the air was forced against a hot steam chest cover *e*, directly

in front of each blower discharge, and, after circulating about the cylinders and steam pipes, poured from the engine room through the escape trunk, to be at once drawn down the supply tube for another superheating circuit. The remedy for this blunder was not difficult; it was effected simply by removing the mushroom top and building the air tube about seven feet up into the air, as shown by the dotted lines. Thereafter the blowers discharged real air instead of a blast hot enough to have come from Tartarus. About a year after these changes had been found necessary on the *Amphitrite*, I noticed that the *Puritan*, not then completed, had the same faulty location of intakes for blowers, and that the absence of downcast ventilators was conspicuous.

Besides the benefits already enumerated as resulting from the changes in the *Amphitrite*, we found that the fire room force could stand several days under steam without breaking down. Previously we had never been able to take the sea with more than four of the six boilers in use, even with liberal help from the deck force. With the improved ventilation, we found we could keep five boilers in use without distress, and this raised the cruising speed to about nine knots. With that as the standard, she recently kept position in a large squadron of modern ships steaming from Hampton Roads to New York. In March last, off Charleston Bar, she ran a full power trial for six hours without exhausting the men in the least; the average speed for that time was 10.72 knots, with wind, sea and current, estimated at one and one-half knots, against her.

A few words about the *Amphitrite's* guns will not be out of place. She has four 10-inch breech-loading rifles in pairs in two turrets, the power for working turrets and guns being hydraulic, furnished by four Davidson pumps with steam and water areas in the ratio of nine to one. The pumps are also arranged in pairs, one pair near each turret, but they are connected by an emergency pipe through which we could, and often did work both turrets with one pair of pumps, or one turret with the pumps more remote from it. The hydraulic pressure was governed by pneumatic accumulators, with pistons and suitable levers acting on the pump throttles; a Rand air compressor was used to charge

the receivers of the accumulators, but it was so small for its work that several hours were necessary to pump up the requisite pressure of 600 pounds. Our safe boiler pressure was only 75 pounds and, when allowance was made for loss caused by the distance the steam was piped, we found this could not transmit through the pumps a greater hydraulic pressure than the needed 600 pounds, so we simply stopped using the air system and saved time and labor.

Some minor defects in the hydraulic system and gun mechanism existed at first, as was natural, but these were overcome by the force on board and, after the first six months, the whole system was as good as one could wish. Turret drill was very frequent and the guns were certainly fired more than any similar ones have been in our service, while all connected in any way with the working of the turrets became skilled to an admirable degree in their duties. The only drawback to this feature of the ship's routine was the difficulty, sometimes experienced in still or rainy weather, of keeping up the full pressure in one boiler to work the hydraulic engines and the usual auxiliaries at the same time. That trouble of course did not exist at target firing, when the ship would be at sea with steam on several boilers.

Service on the *Amphitrite* has prejudiced me in favor of the hydraulic system of working great guns, for I know that the system will work without trouble and can be kept in an always ready condition, but like steam machinery, it requires proper and vigilant supervision. I have read with much interest the paper by Passed Assistant Engineer T. W. Kinkaid in the February number of this JOURNAL, describing the pneumatic system of working the guns and turrets of the *Terror*, and I have seen and heard considerable of that vessel during the fifteen months she has been in commission. It is proper to withhold opinions until her system is declared complete, but it is not amiss, I hope, to surmise that, had she been fitted with a hydraulic system similar to that of the *Amphitrite*, her experimental period might have been ended long ago. A practical comparison of the two systems is pertinent. The two ships, *Amphitrite* and *Terror*, spent some time together in Charleston Harbor last

winter, carrying out the same routine of daily drills and burning coal from the same consignment. For the same sixteen days during that period, neither vessel being under way any day, the *Amphitrite* burned 84.35 tons of coal and the *Terror*, 129.25 tons. As the vessels are the same in size, with boilers exactly the same, and have the same demands upon their auxiliary machinery, it must be that this difference in coal consumption is due to the great air compressors of the *Terror* competing with the *Amphitrite's* hydraulic pumps.

The *Puritan* has been put in service with defects similar to those described in the case of the *Amphitrite*, and her experience thus far indicates that under similar conditions they would lead to the same disasters. In February of the present year, she steamed from New York to Charleston with six of her eight boilers at a rate varying from five to seven knots only; though in the winter season, her engine room averaged about 115 degrees and the fire room was from 140 to 152 degrees. Her chief engineer informs me that thirteen men of the engineers' force were prostrated by heat during that trip. Had she gone on the southern coast in mid-summer, as the *Amphitrite* did, the same suffering and loss of efficiency from heat must have resulted. Like the latter vessel, her machinery gave much trouble and in more serious degree, for she had to be towed the greater part of the distance from Charleston back to New York. While under her own steam on that voyage, she encountered a severe gale, and behaved in it in a manner to bear out the staunch, sea-worthy reputation of the monitor type.

The *Miantonomoh*, unlike the others, has no superstructure over the engines and boilers. In the early part of her commission, in 1892, the highest temperature reached on the working platform in the engine room was 130, and in the fire room, 150 degrees. Owing to the discharge of vapor into the engine room from the feed tank, the air was almost saturated. The heat, moisture and absence of change in the air made very oppressive conditions. Later on, a hatch was opened direct to the air in the after part of the engine room, the feed tank was closed and provided with a discharge to the air, and a separate blower was

put in for the ventilation of the working platform, these changes making a decided improvement. However, not being put on cruiser duty, she did very little steaming, and that always in northern latitudes, so her possibilities for heat were not fully tested. Like the *Terror*, her turrets are without barbettes, a serious fault not shared by the other monitors. The *Terror* has ventilators for her engine and boiler spaces and a good system of forced ventilation besides. The greatest fire room temperature thus far reported from her is 127 degrees, but the engine room has reached 129 degrees.

The modern machinery of the *Monadnock* makes her the best ship of the class, the chief advantage being given by the high pressure boilers available for supplying ample power to the turrets, for speed is not an important requisite in a monitor, though essential in a cruiser. Warships are classed for different military purposes, just as land forces are divided into different arms for different duties, and we appear to be getting our classes of ships jumbled together rather more than utility demands; we are, in fact, trying too much to give our heavy artillery the attributes of cavalry. A perfect fighting ship would comprise the greatest speed, the heaviest armor and the most powerful guns known. These factors are not harmonious and have never yet been combined to make the perfect ship, and probably never can be; the depth of water in harbors, if nothing else, must limit the attempt to give great speed to great weight, for speed adds weight wonderfully fast in itself. The present compromise is the sea-going battleship, which, with moderate speed and fairly heavy armor and armament, is already close to the limit in the matter of draught.

The need for coast defenses in our country is patent to all, and formidable works are now being constructed by the Army at various points. A project is even being seriously considered to build a revolving steel turret on the Romer Shoal at the entrance to New York Bay, and possibly others in other harbors. While this work is in progress or in contemplation, it is fair that the monitor should receive consideration, for a portable steel turret is certainly better than one fixed to one point. If we could get

over the idea of speed and get back to Ericsson's simple project of a fort on a raft, we should be on the right tack so far as monitors and the problem of coast defense are concerned. A *Puritan* or two would be better for the defense of New York Harbor than the biggest fixed turret that could be built, for operations would not then be limited to a region within gunshot of the Romer Shoal, or other selected spot.

The reconstructed monitors dealt with in this paper are certainly not over-swift, but they are fast enough if limited to their proper sphere and not expected to do the duty of a cruiser. A serious fault with them is that their speed, low as it is, is produced by machinery enormously heavy and bulky for the power developed, when compared with modern constructions. This fault is beyond practical remedy with the monitors we now have, because an appeal for new machinery would probably be construed as too much like a project for putting new wine into old bottles; it would not pay, to use a commercial term. As they are, the double-turreted monitors are formidable fighting ships and may be maintained as such for many years, if kept in commission with full crews on board, which is a better method of keeping a ship serviceable than laying it up in ordinary or in reserve. Monitor crews are small at the most, and can be considerably reduced by some changes in organization without disturbing efficiency.

Changes in this direction that suggest themselves on board ship are not perhaps within the scope of this essay, but one or two of them may be briefly spoken of. For instance, on the *Amphitrite* we had four messes for officers, each with its cook, steward and attendants; two warrant officers composed one mess; the steerage mess for about three months had ten members, but for the greater part of two years had only three, and finally two members. The ward room had eleven occupants, and the cabin mess of course had only one member. Without making any change in the places or manner of serving meals, it is plain enough that three of these cooks and three stewards might have been dispensed with, and with them would also disappear three pantries with all their wonderful possibilities for smells and in-

sects. The dynamo engine is always near the engine room or near other auxiliary machinery in use, and might well be attended by the regular watch, thus removing the necessity of having four or more men kept on board to stand watch on one small engine. It would be easy, if one were going into this matter thoroughly, to find other instances in which duties are duplicated and men multiplied unnecessarily. The opportunity for making reductions along the lines of real utility and good sense exists in any type of ship as well as in a monitor.

These monitors might be stationed as harbor defense ships in the principal seaports and required to carry out the established routine, including target practice under way, without being a part of the cruising squadron. Once a year or oftener, they might assemble for squadron drill when, without hampering the evolutions of faster ships of other types, officers and men could gain better experience than the monitor crews now get in squadron drills where their ships are outclassed. My experience has been that these drills give valuable education to the engineer branch. It certainly adds to the efficiency of the ship to get the engineers' force in the habit of regulating speed to a nicety, and of keeping fires, steam and machinery, without undue labor, always ready to answer a sudden signal to get under way for a few minutes or a few hours, as is constantly being demanded on the drill grounds. Though not intended for the instruction of the engineers' force, the drills in which I have participated have benefited that force in a very noticeable manner, and in that way have added much to the ship's usefulness.

Something may be said about the superstructures on these monitors. From a military point of view they are almost worse than worthless, increasing as they do the size of the target to be fired at, and containing an element of great danger in their liability to burn in action. With all the joiner work, furniture, clothing and books peculiar to officers' quarters, and with boats, chests and all sorts of gear stowed on top of them, they constitute in reality altars ready for the torch, and in battle might become funeral pyres. Even with the boats and gear thrown overboard, there would remain sufficient material to make the

whole ship uninhabitable if once set on fire. With the exception of whale boat and gig, which are carried as life boats at davits and can be easily lowered, the boats are stowed inboard on cradles, and must be handled one at a time with a boom and steam winch, which could not be used at all in the presence of an enemy. One hour is a very moderate allowance of time for getting the boats out by present means, and this might be too long in cases of stranding or collision, requiring the ship to be abandoned.

There are some advantages in the superstructures. Chief of these are the increased crew space and the location above deck of the galley and water closets. By quartering officers in the superstructure, all, or nearly all, the after berth deck becomes available for the crew, which is an important consideration. It resulted on the *Amphitrite* in the men being comfortably berthed, and made them the most contented and willing workers with whom I have ever been shipmate. The superstructure, after the original mistakes in ventilation were corrected, furnished a roomy and cheerful habitation for officers, uncomfortable only when at sea in the unusual combination of rough and hot weather.

These advantages apply to peace time, but do not offset the danger of carrying a great mass of combustibles on deck in time of war. It has been proposed to remove the superstructures entirely, but that seems a too heroic remedy for a trouble that can be greatly lessened. The officers' quarters should be below, and the superstructure used as berthing space for part of the crew; except for the galley and the closets, it should be an empty shell without wooden fittings of any description. It would then cease, in great measure, to be dangerous as a fire trap, and there would be no crowding of officers and men on the berth deck, with the galley for a room mate. The *Terror* is fitted somewhat in that manner now, though she has considerable wood work in her superstructure, in the quarters for warrant officers and in the offices for the number of writers needed to do the clerical work of our ships.

These impressions of our monitors have been set down at irregular intervals after quitting duty on one of them, and while

getting accustomed to a different organization and routine in a much larger ship, which circumstance may account in a way for the lack of continuity in what I have written. Though lacking in many of the comforts usually found in other classes of ships, the monitor can be made an agreeable habitation for officers and men and, which is of more importance, it can be made to work successfully. The cost of operating and the number of the crew required are small in comparison with the possible destructive and defensive results that may be achieved, and the first cost is also small when measured by the same standard. No other type of war vessel is so essentially American or so essential to the maintenance of our defensive naval policy.

THE CONTRACT TRIALS OF THE U. S. GUNBOATS *VICKSBURG* AND *NEWPORT.*

By Chief Engineer H. N. Stevenson, U. S. N.

The composite single screw gunboats *No. 11, Vicksburg*, and *No. 12, Newport*, were built by the Bath Iron Works at Bath, Maine. The contracts were signed November 15, 1895, and both were launched on December 5, 1896. The designs and specifications were furnished by the Navy Department, the contract price for each being $229,400, without the spars, rigging or spare parts, and some of the equipment as noted elsewhere. They are sister ships, built from the same plans, and differ only in interior division, it being the intention to fit the *Newport* as a practice vessel for the Naval Academy, for which purpose the gun deck is to be specially arranged. They are of the composite construction, with steel plating above, and wood planking below the water line. They have a flush spar deck, a gun deck with offices and cabin at after end, and a berth deck forward and aft of the machinery space. There is a double bottom under the engine and boilers, which can be used for the storage of fresh water. The bulkheads on ten frames are made water tight below the gun deck, as are also the coal bunkers, store rooms and hold. There is no protective deck, but the coal bunkers, which surround the boilers and engine, extend to the gun deck and give protection when full. There is a trimming tank forward in the bow, and another one at the stern. The rig is to be barkentine, and the screw is made to disconnect so that the propeller can revolve when under sail. There are to be seven boats including a steam cutter. The main battery will consist of six 4-inch B. L. Rifles and the secondary battery, of four 6-pounders and two 1-pounders. There are no torpedo tubes.

The contracts required an average speed of 12 knots for four

consecutive hours, subject to a penalty at the rate of $10,000 per knot for a less speed. There was no premium for an excess.

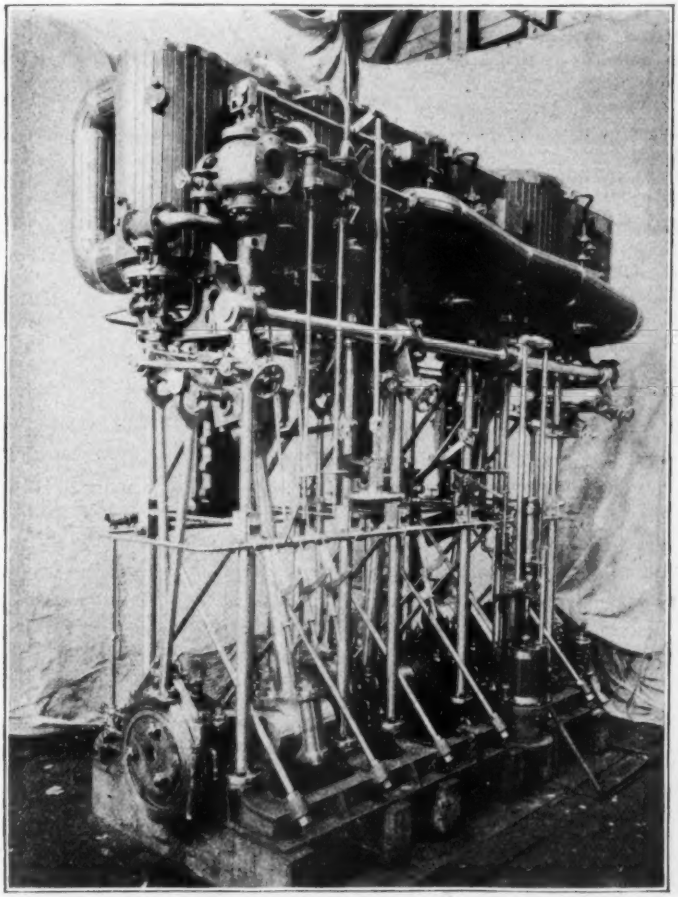
HULL.

Length between perpendiculars, feet and inches	167–9
on L.W.L., feet	168
over all, feet	204
Beam, feet	36
Ratio of length to beam	1 : 4.66
Depth of hold, flat keel to top of spar deck beams, feet and inches	22–3½
Draught, mean, normal, feet	12
Displacement, normal	1,010
per inch, at L.W.L., tons	10.73
Area of immersed midship section to L.W.L., square feet	354
L.W.L. plane, square feet	4,510
Center of gravity of L.W.L. abaft midship section, feet	3.71
buoyancy below L.W.L., feet	4.59
abaft midship section, feet	.58
gravity above center of buoyancy, feet	6.41
Transverse metacenter above center of buoyancy, feet	10.58
Longitudinal metacenter above center of buoyancy, feet	201.90
Transverse G.M., "metacentric height," feet	4.07
Block coefficient for displacement	.482
Cylindrical coefficient for displacement	.503
Midship section coefficient	.820
L.W.L. coefficient	.743
Number of frames	119
Distance between frames, inches	20
Sail area, square feet	11,253

MAIN ENGINE.

There is a single screw engine of the vertical, inverted, direct-acting, triple expansion type, designed by the Navy Department. It is arranged in the usual manner with the high pressure cylinder forward, the cranks being 120 degrees apart and following in the order H.P., I.P. and L.P., the cranks turning to port from the top center. The cylinders are jacketed on top and sides, besides being well clothed with asbestos and wood covering. The H.P. cylinder has a piston valve; the other cylinders, double-ported slide valves with balance pistons connecting with the condenser. The valve gear is the ordinary Stephenson link motion with double bar links. The engine was designed to develop 800 I.H.P., when running at 150 revolutions per minute,

with a steam pressure of 180 pounds in the boilers. The framing of the engine consists of a cast iron bed plate made in two parts, with six shaft bearings. The cylinders are supported by wrought steel columns resting on the bed plate. The cast iron guides for the crosshead slippers are secured to the cylinders



TRIPLE EXPANSION ENGINE OF U. S. S. "VICKSBURG" AND "NEWPORT."

and the columns. The crank shaft is in three interchangeable sections. The condenser is separate from the engine. The air pump is worked from the L.P. crosshead. The circulating pump, of the centrifugal type, is driven by independent engines.

The following are some of the principal dimensions of the engine.

Number of cylinders		3
Diameter of cylinders, inches	H.P.	15½
	I.P.	23½
	L.P.	36
Stroke, inches		30
Diameter of H.P. valve, inches		8½
Width and height of L.P. valve, inches		22½–23⅜
L.P. valve, inches		34½–25½
Diameter of piston rods (all), inches		3⅜
Length of connecting rods, center to center, inches		66
Distance between centers of cylinders, feet and inches		3–8
Volume swept by piston per stroke, cubic feet mean	H.P.	3.09
	I.P.	7.45
	L.P.	17.59
Ratios of net areas of pistons	H.P. to I.P.	2.37
	I.P. to L.P.	2.35
	H.P. to L.P.	5.57
Crank shaft, length, each section, feet and inches		3–8
diameter, inches		7
length, each bearing, inches		8
axial hole, diameter, inches		3½
Crank pins, diameter, inches		7½
length, inches		8½
axial hole, diameter, inches		3½
Propeller shaft, length, feet and inches		21–9
diameter and axial hole, after section, inches		7½–3½
Thrust shaft, diameter, inches		7
axial hole, inches		3½
number of thrust collars		7
thickness of thrust collars, inches		1¼
diameter of thrust collars, inches		10½
area of thrust surface, square inches		336.8

PROPELLER.

The propeller is left-handed, has three adjustable blades, and is made of Hyde manganese bronze. The mean pitch is adjustable from 9 feet 10 inches to 10 feet 10 inches.

Number of blades	3
Diameter, feet	10
of hub, feet and inches	1–11
Thickness of blade at root, inches	$3\frac{1}{4}$
Helicoidal area, square feet	23.34
Disc area, square feet	18.66
Pitch as set, mean, feet, *Vicksburg*	10.627
Newport	10.453
Distance of center of hub above base line, feet	5.75
Top of propeller, immersed, inches	$15\frac{3}{4}$

CONDENSERS.

The main condenser shell is cylindrical, of plate steel, with Hyde manganese bronze ends and tube plates. It is placed on the starboard side of the engine room, resting on the feed water tank and being also secured to the bulkhead. The circulating water passes through the tubes.

Number of tubes in condenser	942
Length between tube sheets, feet and inches	7–3
Diameter of tubes, outside, inch	$\frac{5}{8}$
Cooling surface, square feet	1,118
Ratio total cooling surface to total H.S.	1 : 2.26

There is also an auxiliary condenser on the port side of the engine room, with a cooling surface of 150 square feet.

AIR AND CIRCULATING PUMPS.

The main air pump is driven from the L.P. crosshead, the pump cylinder being $13\frac{1}{2}$ inches in diameter, and the stroke, 10 inches. The valves are bronze discs.

The circulating water is supplied by one double inlet centrifugal pump, the diameter of the runner being 20 inches, and of the suction and discharge pipes, 7 inches. The pump is arranged to draw from the sea or the bilge, and to discharge into the condenser, or directly overboard, by means of connecting pipes and by-pass valves.

FEED AND OTHER AUXILIARY PUMPS.

All of the pumps are of the M. T. Davidson make and have metal valves in the water ends. The following pumps are installed.

In the engine room.	*Steam cylinder, ins.*	*Water cylinder, ins.*	*Stroke, ins.*
1 Vertical main feed	8	4½	10
1 Vertical water service	9	5	10
1 Vertical fire and bilge	10	6¼	10
1 Horizontal air and circulating, for auxiliary condenser	4½	water 6 air 5	6 ..
1 Horizontal distiller pump	3½	2	4
1 Vertical distiller pump	3½	2½	4
In fire room.			
1 Vertical auxiliary feed	10	6¼	10

Distilling Apparatus.—This consists of a Baird evaporator with straight tubes, containing 120 square feet of surface, and two double distilling coils. The rated capacity is 3,000 gallons per day.

Ash Hoist.—There is one Williamson Bros.' ash hoist engine with two cylinders, 4½ inches in diameter by 4½ inches stroke.

Forced Draft.—The forced draft is supplied by two Sturtevant blowers, located in the upper after part of the fire room, one on each side. They discharge into ducts which run over the boilers and join at the back; from here a branch duct is led down to a trunk through each back connection and discharges under the bridge wall into the back of each ash pan. A regulating damper is placed in each duct, and is operated by a lever at the front of the boiler. Each blower is driven by a pair of single-acting, enclosed engines with cranks at 180 degrees. The cylinders are 3½ inches in diameter and the stroke is 2½ inches.

Diameter of fan, inches	36
Area of inlet, square inches	604
Area of discharge, square inches	396

Ventilation.—There are two Sturtevant blowers for ventilation, one situated in the engine room for the after berth deck, and one on the berth deck for the forward part of the ship.

Other Machinery.—The electric light plant, steam windlass, steering engine, workshop machinery and hoisting engine were not included in the original contract. A Hyde windlass, a Hyde double hoisting engine and a Williamson Bros.' steering engine have been placed on board, but no electric light or workshop plant has yet been installed.

The windlass has two steam cylinders, each 6 inches in diameter and 8 inches stroke.

The two hoisting engines, each with two 6-inch cylinders and a stroke of 6 inches, can be worked together, or by throwing out the clutches, can be worked separately.

The steering engine has two cylinders, each 6 inches in diameter and 6 inches stroke.

BOILERS.

There are two single-ended, horizontal, return fire tube boilers, each with two corrugated furnaces. They are built of two courses of two sheets each, the tops of the front and back heads being rounded. A Craig circulating apparatus is fitted to each boiler in addition to the usual mountings.

DATA FOR ONE BOILER.

Shell, length over heads, feet and inches	10–6
diameter, mean, feet and inches	10–6
thickness, inch	1
number of courses	2
sheets in course	2
Furnaces, number	2
diameter (least inside), inches	36
(greatest inside), inches	39
thickness, inch	$\frac{17}{32}$
length of grates, inches	78
Tubes, number of ordinary No. 9, B.W.G	132
stay No. 6, B.W.G	64
diameter all tubes, outside, inches	$2\frac{3}{4}$
internal diameter, ordinary, inches	2.45
stay, inches	2.34
length between tube sheets, feet and inches	7–6
center to center of tubes, vertically, inches	$3\frac{3}{4}$
horizontally, inches	$4\frac{1}{4}$
thickness of tube sheets, inch	$\frac{3}{4}$
Thickness of heads, inch	$\frac{3}{4}$
combustion chamber, inch	$\frac{9}{16}$
Tube heating surface, square feet	1,058.40
Plate heating surface, furnaces, square feet	82.06
combustion chambers, square feet	121.56
Total heating surface, square feet	1,262.02
Grate surface, square feet	39
Ratio G.S. to H.S	1 to 32.06
Area through tubes, square feet	6.23
Steam space, normal, cubic feet	166

TOTALS FOR TWO BOILERS.

Heating surface, square feet	2,524.04
Grate surface, square feet	78
Area through tubes, square feet	12.46
Volume steam space, cubic feet	332
Area water surface, square feet	193
Net area of smoke pipe, square feet	14.18

RATIOS.

Total G.S. to H.S.	1 to 32.06
Area through tubes to G.S.	1 to 6.26

Coal Bunkers.—There are eight coal bunkers, the total capacity of which, based on 42 cubic feet to the ton, is 240 tons. These bunkers are arranged alongside of the engine and boilers, between the engine and boilers, and forward of the boilers.

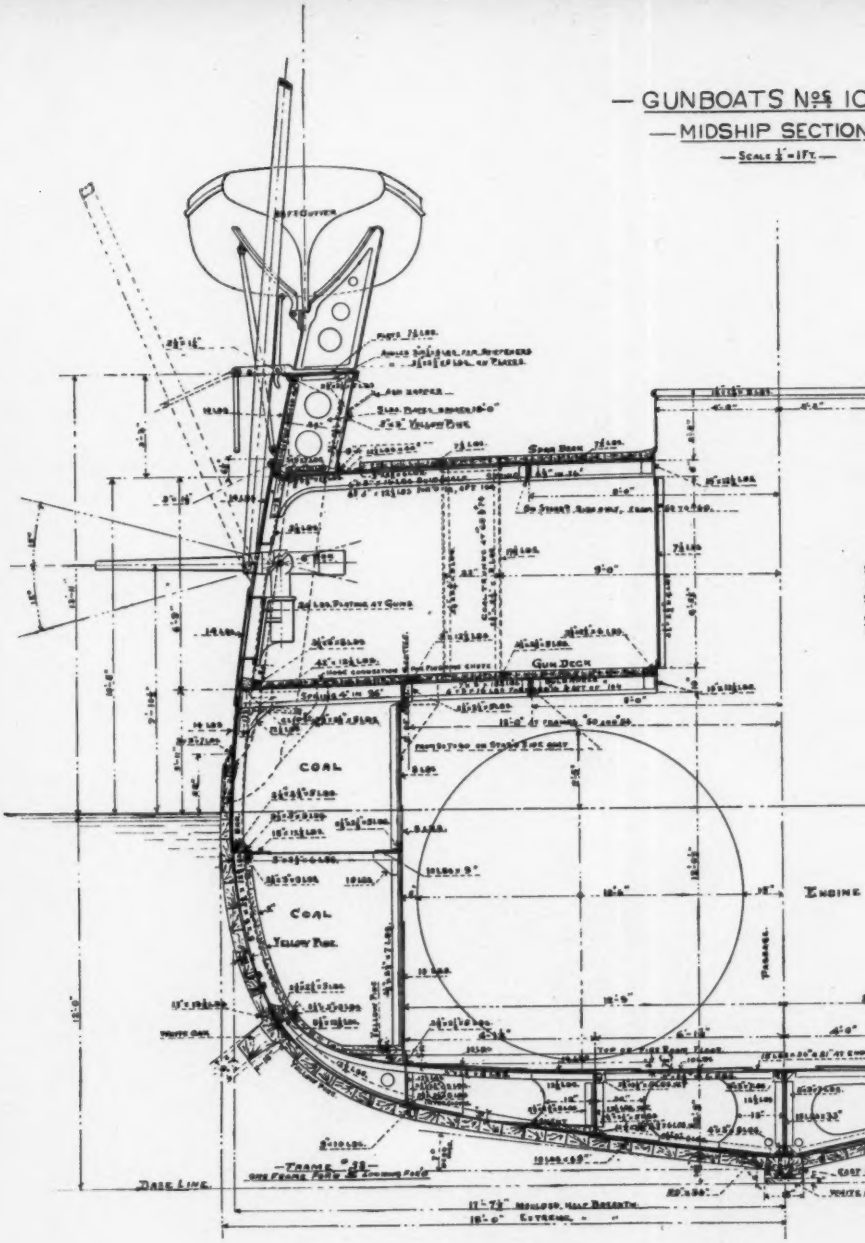
THE TRIALS.

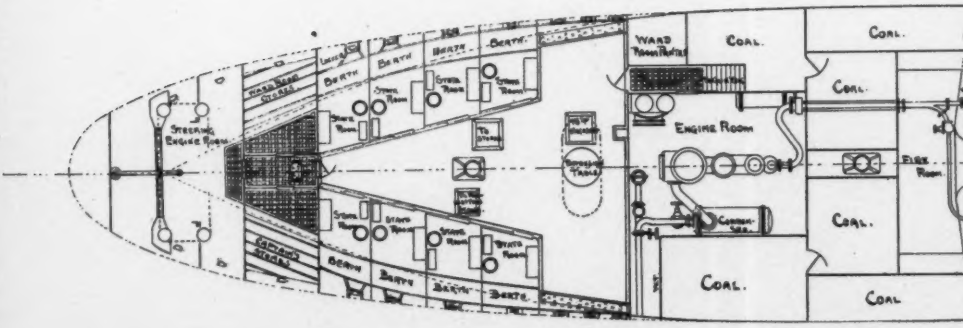
The official trial of the *Newport* was made on May 27, and that of the *Vicksburg*, on May 29, 1897. Both vessels left the dock of the contractors in the morning, and returned in the afternoon of the same day, having completed all the trials. The speed for the four hours' trial was calculated from the mean number of revolutions of the propeller and a curve for speed and revolutions, which had previously been determined by progressive runs over a measured base line. The contractors have had for their own use for some years a measured mile course near the mouth of the Kennebec river and on the east side of Southport Island, in Boothbay Harbor. Each end of this course is marked by range poles and there is ample room for turning. Prominent objects on shore serve as ranges for steering. The depth of water varies from 17 to 20 fathoms. Before the trials, the base of one nautical mile was carefully verified by naval officers from Coast Survey marks. On the day of the trials, a run of about two and one-half hours from the works of the contractors brought the vessel to the measured mile course. Five sets of runs were made, each set consisting of a run with and against the tide. The first set was made at easy full speed, then three sets reduced successively by about five revolutions per minute each, and then one more at a reduction of ten revolutions. The throttle was regulated and set for the desired engine speed before the com-

— GUNBOATS Nos 10

— MIDSHIP SECTION

— Scale ½" = 1Ft —

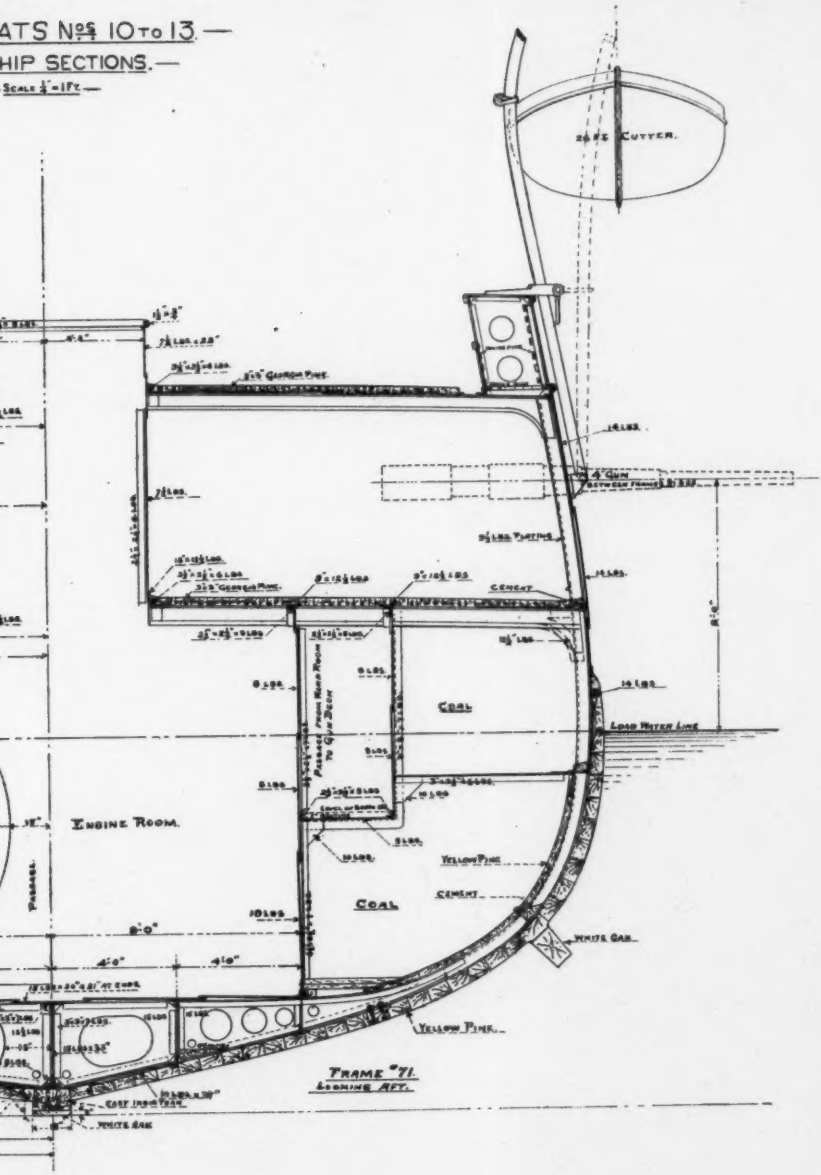


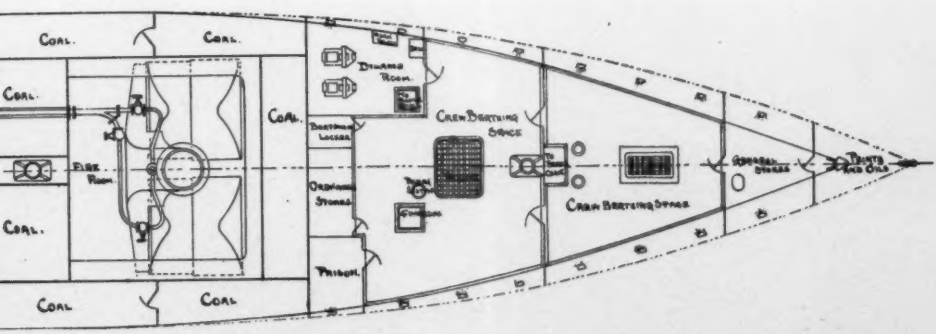


ATS Nos 10 to 13. —

HIP SECTIONS. —

Scale ½" = 1Ft. —





mencement of each double run, and no change was made during the runs and the turn. From the data thus obtained, a mean curve of speed and revolutions was constructed. In obtaining the revolutions, two independent counters were observed in the engine room, and a Weaver electric recorder was set up in one of the staterooms on the gun deck. This instrument, which was described and illustrated on page 86 of Volume III, records on a slip of moving paper, by means of electricity, the time from a break circuit chronometer, the revolutions of the engines and the time of passing the ranges. During the trials, owing to the non-arrival of the break circuit chronometer, the time was marked from two ordinary chronometers. Indicator cards were taken on each run. The following table gives the results of the progressive trials. It will be noticed that a stronger tide was running when the *Newport* was tried.

PROGRESSIVE SPEED TRIALS U. S. S. *VICKSBURG*.

Run.	*Speed, knots.*	*Revols. per minute.*	*Total I.H.P.*	*Mean slip, per cent.*
1	12.676	144.4	1,103.40	
2	12.456	144.95	1,062.22	17.2
3	12.544	142.5	1,032.61	
4	12.361	142.8	1,030.13	16.75
5	12.06	134.38	866.58	
6	11.746	132.68	825.33	15.01
7	11.603	127.27	722.54	
8	11.268	127.14	710.25	14.27
9	10.666	115.55	535.71	
10	10.375	115.21	524.36	13.05
	U. S. S. *NEWPORT*.			
1	11.755	141.65	1,008.71	
2	12.51	138.89	951.13	18.51
3	11.58	136.82	925.84	
4	12.326	138.93	941.35	15.97
5	11.613	138.92	959.55	
6	12.255	136.85	905.04	16.07
7	11.193	131.8	839.09	
8	11.379	127.2	688.77	15.51
9	10.056	116.06	552.07	
10	10.810	117.08	564.34	13.89

Immediately after the progressive trials were completed, and so soon as the boilers and engine could be brought to maximum conditions, which took about one-half hour, the consecutive four hours' trial was begun, the vessel making a run out to sea for that purpose.

Both trials were made successfully. At extreme speed there was moderate vibration of the hull of both vessels. The engines worked well without water on any of the bearings, and the boilers steamed freely without priming. All of the auxiliaries worked satisfactorily. The coal used was screened Pocahontas of good quality, and was stowed in the bunkers in bags of 100 pounds each. The method of trial by standardized revolutions proved successful in every particular, in easily, accurately and quickly determining the speed during the official trials.

The following data give the results of the four hours' trial.

CONTRACT TRIAL DATA.	*Vicksburg.*	*Newport.*
Draught of water, beginning of trial, forward, feet and inches	11–3½	11–2
aft, feet and inches	12–1	12–4
end of trial, forward, feet and inches	11–2	11–0½
aft, feet and inches	12–0½	12–3½
mean, forward, feet and inches	11–2¾	11–1½
aft, feet and inches	12–0¾	12–3¾
average on trial, feet and inches	11–7¾	11–8½
Displacement, mean, tons	964	972
Area immersed midship section	342	344
Wetted surface, square feet	7,040	7,060
Speed, mean, knots	12.71	12.29
Slip of screw per cent	17.39	16.49
Speed^3 × area of immersed midship section ÷ I.H.P. (*A*)	636.3	644.8
Speed^3 × displacement$^{\frac{2}{3}}$ ÷ I.H.P. (*A*)	181.5	183.9
I.H.P. (*A*) per 100 square feet wetted surface	15.68	14.03
SYNOPSIS OF STEAM LOG.		
Revolutions of main engine, per minute	146.57	142.68
Piston speed, feet, per minute	732.85	713.40
Steam pressure, in boilers, per gauge	186	182
at engines, per gauge	179.9	177.5
1st receiver, absolute	89.9	76.1
2d receiver, absolute	39.3	34.9
Vacuum in condenser, inches	26.3	25.5
Throttle valve opening	wide.	wide.
Revolutions of circulating pump per minute	484	487
Double strokes of feed pumps, per minute	47.1	52.9
fire and bilge pumps, per minute	64.5	78.5
water service pump, per minute	42	21.6

	Vicksburg.	*Newport.*
Temperature in degrees Fahrenheit:		
Engine rooms	91	83
Injection	48	47
Discharge	82	88
Feed water in tank	84	108
at boilers	217	203
Fire rooms	122	89
Air pressure in ash pans, inch of water	.97	.95
Revolutions of forced draft blowers, average, per minute	709 6	799.1
Mean pressure in cylinders, H.P.	69 80	83.89
I.P.	39.04	30.80
L.P.	19.40	16.83
Aggregate equivalent pressure referred to L.P. piston	48.57	45.04
I.H.P.:		
H.P. cylinder	276.09	322.60
I.P. cylinder	371.90	258.38
L.P. cylinder	436.38	368.26
Collective, main engine	1,084.37	976.24
Circulating pump	19.48	14.01
Main feed pump	6.85	7.67
Two forced draft blowers	7.03	10.29
Other auxiliaries	.51	.54
Collective main engine and circulating pump (*A*)	1,103.85	990.25
Total all machinery in use	1,118.24	1,008.75
Indicated thrust (main engine only), pounds	18,513	16,021
Indicated thrust per square foot of developed blade area, pounds	793	686
Indicated thrust per square inch of thrust surface, pounds	55	47.6
Cubic feet swept per minute by L.P. piston, per I.H.P. main engine	4.75	5.14
Square feet of cooling surface per I.H.P. (*A*)	1.01	1.13
H.S. per total I.H.P.	2.26	2.50
I.H.P. per square foot grate surface, total	14.34	12.93
ton machinery (penalty weight)	9.85	8.89
Coal per hour, pounds	2,375	2,065.3
total I.H.P., pounds	2.12	2.05
square feet of G.S., pounds	30.45	26.48
H.S., pounds	.94	.82

NOTE.—As the hulls of the above gunboats and the *Annapolis* are almost identical, and to avoid unnecessary duplication of cuts, these cuts have been divided, part being in this paper and the rest in the next paper on the trial of the *Annapolis*.

By noting that the boilers are cylindrical or water tube, as the case may be, and that the engines differ, these cuts will apply to either the *Annapolis* or the *Vicksburg* and *Newport*.—EDIT.

THE CONTRACT TRIAL OF THE U. S. GUNBOAT *ANNAPOLIS.*

By Passed Assistant Engineer C. H. Mathews, U. S. Navy.

The *Annapolis* is a composite, single screw gunboat of about 1,000 tons, built at the Crescent Ship Yard, Elizabethport, N. J. This vessel was launched December 23, 1896, and had her official trial on April 22, 1897.

The bunkers extend up to the main deck and partially protect the engines and boilers. The double bottom extends under the machinery space. The vessel is rigged as a barkentine.

The battery consists of six 4-inch rapid fire rifles, one on the forecastle, one on the quarter deck aft, and four below on the main deck, the two guns on the upper deck being protected by shields; four 6-pounder rapid fire guns on the main deck, two forward and two amidship; and two 1-pounder rapid fire guns abreast of the engine room on the hammock berthing.

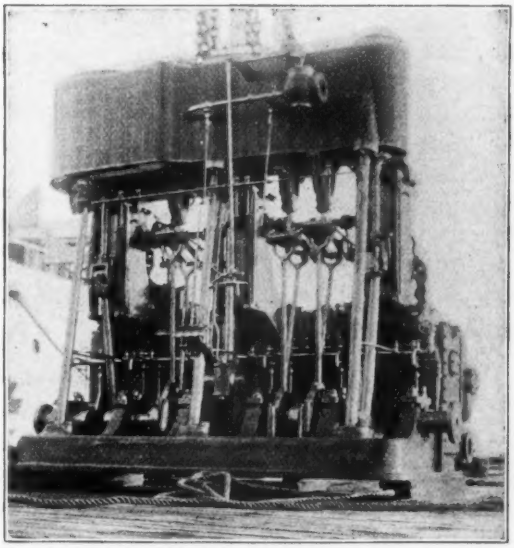
There are seven boats: a steam cutter, sailing launch, two sailing cutters, two whale boats and one dinghy, the dinghy being carried in the sailing launch.

The contract required an average speed of 12 knots for four consecutive hours, subject to a penalty at the rate of $10,000 per knot for a speed below 12 and over 11 knots. There was no premium attached to the contract.

HULL.

Length between perpendiculars, feet	168
over all, feet and inches	203–6½
Beam, feet	36
Ratio of length to beam	4.6
Depth of hold, top of flat keel to top of main deck beams, feet and inches,	21–10½
Draught, mean, seagoing trim (normal), feet	12
Displacement (normal), tons	1,017
Tons per inch L.W.L.	10.73

Area of immersed midship section L.W.L., square feet	357
L.W.L. plane, square feet	4,512
Center of gravity of L.W.L. abaft midship section, frame No. 59, feet and inches	4–2¼
Center of buoyancy above bottom of keel, feet and inches	7–3
aft of midship section, frame No. 59, inches	11¼
Transverse metacenter above center of buoyancy, feet and inches	10–6½
Longitudinal metacenter above center of buoyancy, feet	200
Block coefficient for displacement	.49
Cylindrical coefficient for displacement	.59
Midship section coefficient	.82
L.W.L. coefficient	.74
Number of main frames	113
water tight compartments below main deck and including double bottoms	28



MAIN ENGINE.

The engine is of the vertical, inverted, direct-acting, three cylinder, triple expansion type. The cylinders are well lagged with magnesia and wood covering. The high pressure cylinder has one piston valve, while the intermediate and low pressure

cylinders are each fitted with a double-ported slide valve; all valves are worked by the Stephenson link motion with double bar links. The intermediate and low pressure valves are fitted with balancing cylinders which connect with the condenser.

The main engine was designed to develop 800 I.H.P., including the power of the main circulating pump, when running at 160 revolutions per minute, with a steam pressure of 200 pounds per square inch in the boilers.

The framing of the engine at the back consists of the body of the condenser, with rectangular cast iron housings bolted to the cylinders at the top and to the bed plate at the bottom; three inclined wrought steel columns form the framing in front. The bed plate is of cast iron and supported on the inner bottom.

The crank shaft is made in three interchangeable sections. The shafts, piston rods, connecting rods and working parts are made of mild open-hearth steel.

The piston rods and valve stems are oil-tempered and ground to true cylinders.

DATA OF MAIN ENGINE.

Number of cylinders		3
Diameter of cylinders, inches	H.P.	15
	I.P.	24½
	L.P.	40
Stroke, inches		28
Diameter of H.P. valve, inches		8
Width and height of I.P. valve, inches		20½ × 28 9/16
L.P. valve, inches		40 × 31¾
Diameter of piston rods (all), inches		3⅝
Length of connecting rods, center to center, inches		63
Distance between centers of cylinders, feet and inches		4–6
Volume swept by pistons per stroke, cubic feet	H.P.	2.86
	I.P.	7.63
	L.P.	20.28
Volumetric cylinder clearance (mean of the two ends), cu. ft.,	H.P.	.39
	I.P.	.66
	L.P.	2.23
Ratios of net areas of pistons	H.P. to I.P.	2.66
	I.P. to L.P.	2.66
	H.P. to L.P.	7.11
Crank shaft, length, each section, feet and inches		4– 6
diameter, inches		7½

Crank shaft, length, each bearing, inches	8
axial hole, diameter, inches	3½
Crank pins, diameter, inches	7¼
length, inches	8½
axial hole, diameter, inches	3½
Propeller shaft, length, feet and inches	21–10
diameter and axial hole, inches	7– 3½
Thrust shaft, diameter, inches	7
axial hole, inches	3½
number of thrust collars	7
thickness of thrust collars, inches	1⅞
diameter of thrust collars, inches	12¾
surface of thrust collars, square inches	624.35
Line shaft, length, feet and inches	20– 8½
diameter, inches	7
axial hole, diameter, inches	3½

PROPELLER.

The propeller is a solid, four-bladed, true screw made of manganese bronze.

Number of blades	4
Diameter, feet and inches	9–6
Helicoidal area, square feet	30
Disc area, square feet	70.88
Pitch, feet	11
Ratio of pitch to diameter	1.158 to 1
Distance of center of hub above lowest point of keel, feet and inches	5–9

CONDENSERS.

The main condenser casing is of cast iron, in three sections, and forms a part of the engine framing.

Number of tubes in condenser	675
Length between tube sheets, feet	11
Diameter of tubes, outside, inch	⅝
Cooling surface, square feet	1,241
Ratio total cooling surface to total H.S.	1 to 2.92

Auxiliary Condenser.—There is one auxiliary condenser of the Davidson type, with combined air and circulating pump. The condensing surface is 150 square feet.

Air Pump.—The air pump is independent, and of the vertical, double, single-acting, Davidson pattern.

Steam cylinder, diameter, inches	7
Pump cylinder, diameter, inches	11
Stroke, common, inches	12

Circulating Pump.—This centrifugal pump is independent and is fitted to draw from the sea, the main drain and from the engine room bilge, and to deliver into the condenser. The diameter of the runner is 22, of the suction, 7, and of the discharge, 7 inches. The pump is driven by two single engines, with a cylinder diameter of 5, and a stroke of 5 inches.

Feed and other Auxiliary Pumps.—There are in the engine room one main feed pump, one fire and bilge pump and one auxiliary pump for fire and distilling; and in the fire room, one auxiliary feed pump. These pumps are all of the Davidson pattern.

The main feed pump has a steam cylinder 8 inches, and a water cylinder $4\frac{1}{2}$ inches in diameter, and a stroke of 10 inches.

The auxiliary feed pump in the fire room has a steam cylinder 10 inches, and a water cylinder $6\frac{1}{4}$ inches in diameter, and a stroke of 10 inches.

The fire and bilge pump is of the same size as the auxiliary feed pump.

The engine room auxiliary pump, for fire and distilling purposes, has a steam cylinder 9 inches, and a water cylinder 5 inches in diameter, and a stroke of 10 inches.

Besides these independent pumps, there are two single-acting plunger pumps (diameter of cylinder and stroke, 4 inches), worked by eccentrics from the main engine shaft, and used for sanitary and bilge purposes.

Forced Draft.—The forced draft is supplied by two 42-inch Sturtevant blowers, drawing air from the fire rooms and delivering it into the air ducts leading to the ash pits. The fans are driven by enclosed double engines, the cylinders being 4 inches in diameter, and the stroke, 3 inches. The area of the induction nozzle is 594, and of the eduction nozzle, 316 square inches.

Ventilation.—There are two steam Buffalo Forge Co.'s blowers, arranged to work either on the exhaust or supply system. One

blower is placed forward on the berth deck, and the other aft on the gun deck.

Ash Hoist.—The ash hoist consists of two single cylinders, direct pull engines, hoisting by a continuous wire rope.

Distilling Apparatus.—The distilling apparatus consists of an evaporator and two distillers, having a capacity of 3,000 gallons of potable water per twenty-four hours. These are placed in a pocket in the thwartship bunker on the port side of the fire room.

BOILERS.

There are two water tube boilers of the Babcock & Wilcox pattern. Each boiler is composed of two decks of tubes, the lower containing 13 sections of 4-inch tubes placed three rows high, and the upper containing 13 sections of 2-inch tubes placed 10 rows high.

The tubes are 7 feet 6 inches long, connected at their ends by open-hearth, forged steel, staggered headers; the tubes are secured therein by being expanded into bored holes. The headers are provided with hand holes, placed opposite the end of each tube, of sufficient size to permit the cleaning, removal and renewal of tubes.

The different sections are connected to a steam and water drum, and also to a blow-off connection or mud drum, by means of lap-welded wrought iron tubes 4 inches in diameter, expanded into bored holes.

The steam and water drums are 42 inches in diameter and 10 feet 9 inches long, made of open-hearth steel $\frac{19}{32}$ inch thick, with the longitudinal seams butt-strapped inside and outside and having six rows of rivets.

The mud drum is 6 inches square and 93 inches long, with hand holes and nozzles for a 2-inch blow-off pipe.

The feed water heater is placed in the uptake, the tubes being 2 inches in diameter and 6 feet 8 inches long, expanded at their ends into wrought boxes.

The boilers are surrounded with an air tight casing of non-conducting material, backed by sheet iron plates, braced with angle iron and bolted to the foundations.

The fronts of the boilers are of wrought iron, and contain three fire doors, two ash pit doors and large doors for access to the ends of the tubes.

The boilers are fitted with an air compressor, tank and blowing apparatus for cleaning the exterior of the tubes.

The two boilers contain 98 square feet of grate surface and 3,620 square feet of heating surface.

DATA FOR ONE BOILER.

Length, feet and inches	11–7
Width, feet and inches	9–6
Height, feet and inches	11–0
Steam and water drum, diameter, inches	42
thickness of shell, inch	$\frac{13}{32}$
Furnace, number	1
length, feet and inches	6–1½
width, feet	8
Tubes, number of 4-inch	57
thickness, B.W.G. No.	6
number of 2-inch	260
thickness, B.W.G. No.	8
Heating surface, boiler, square feet	1,575
heater, square feet	235
Total heating surface, square feet	1,810
Grate surface, square feet	49
Ratio of heating to grate surface	37 : 1

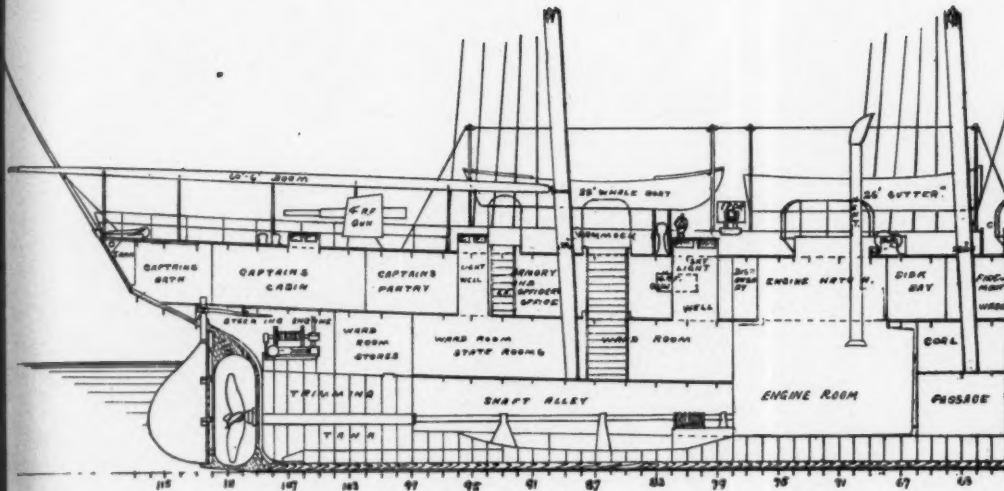
Coal Bunkers.—There are eight coal bunkers with a total capacity, based on 45 cubic feet to the ton, of 230 tons.

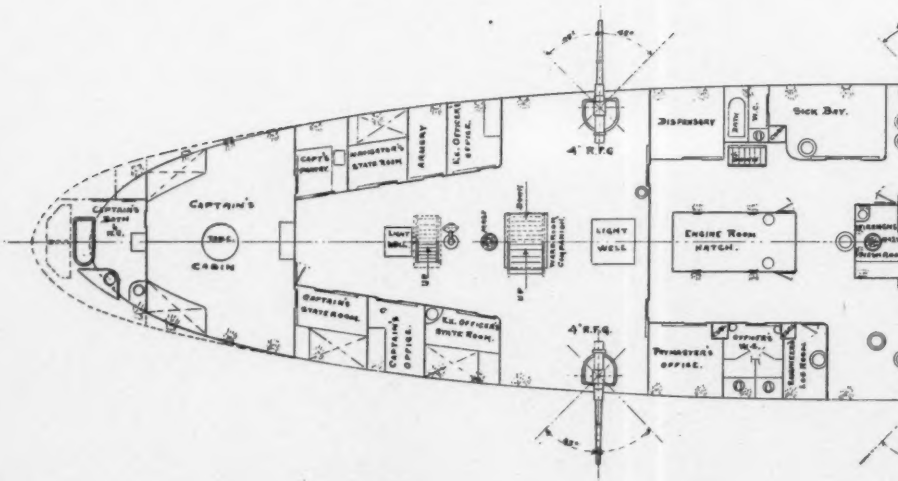
Weights.—The following weights may be used to show the relative weight and power.

Weight of engine proper, inclusive of bed plate, framing, valve gear, valves, crank shafts, cylinders, hand gear, relief valves, receiver pipes, lagging, condenser with main exhaust pipe, tons	20.10
One main boiler, empty, with fittings and lagging, tons	21.00
Water in one boiler to steaming level, tons	4.00
Main circulating pump and engine, ton	0.47
Main air pump and engine, ton	0.70

THE TRIAL.

The official trial was run on Thursday, April 22, 1897, over a course of 24 nautical miles off Bridgeport, Conn. The *Annapo-*


CAPTAIN'S BATH
CAPTAIN'S CABIN
CAPTAIN'S PANTRY
WARD ROOM STORES
WARD ROOM STATE ROOMS
TRIMMING
SHAFT ALLEY
ENGINE ROOM
PASSAGE
WARD ROOM
SICK BAY
COAL


CAPTAIN'S CABIN
DISPENSARY
SICK BAY.
ENGINE ROOM HATCH.
LIGHT WELL
4" R.F.G.
PAYMASTER'S OFFICE.

GUNBOATS Nos 10–
INBOARD PROFILE

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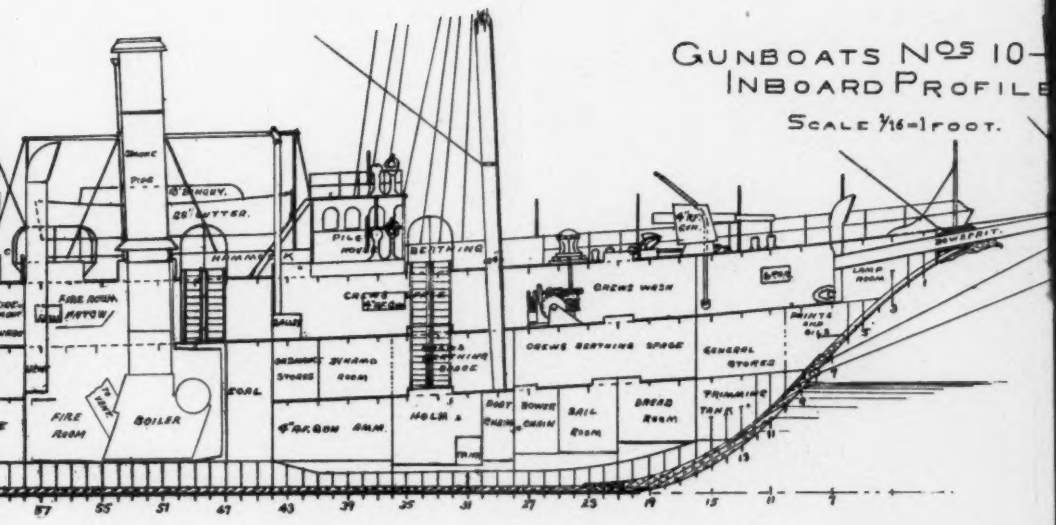

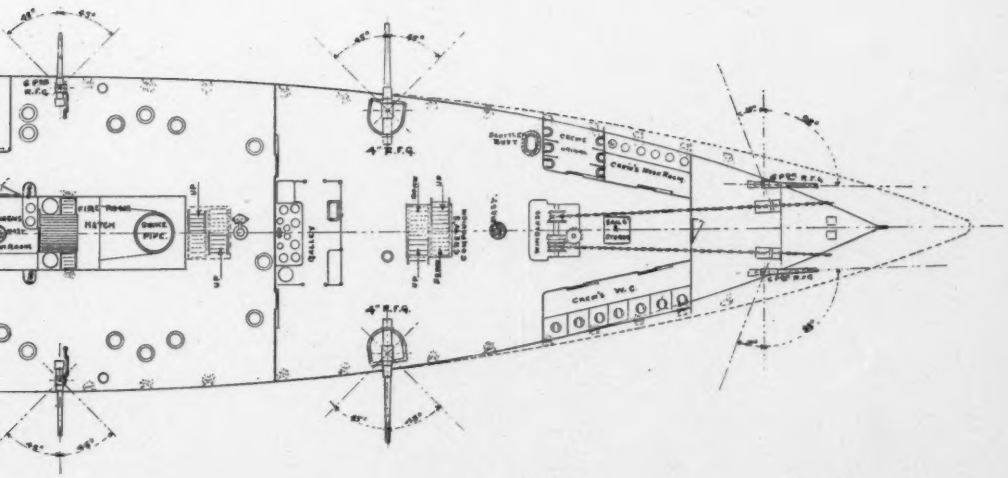

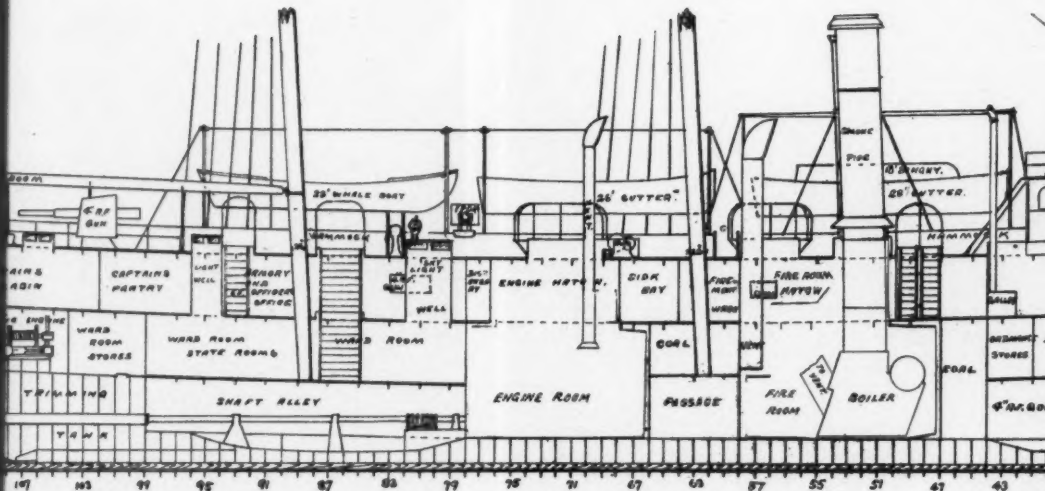
25' WHALE BOAT
25' CUTTER
25' CUTTER
CAPTAIN'S PANTRY
ARMORY AND OFFICERS OFFICE
WARD ROOM STORES
WARD ROOM STATE ROOMS
WARD ROOM
SHAFT ALLEY
ENGINE ROOM
PASSAGE
FIRE ROOM
BOILER
COAL
COAL
TRIMMING
TANK
107
103
99
95
91
87
83
79
75
71
67
63
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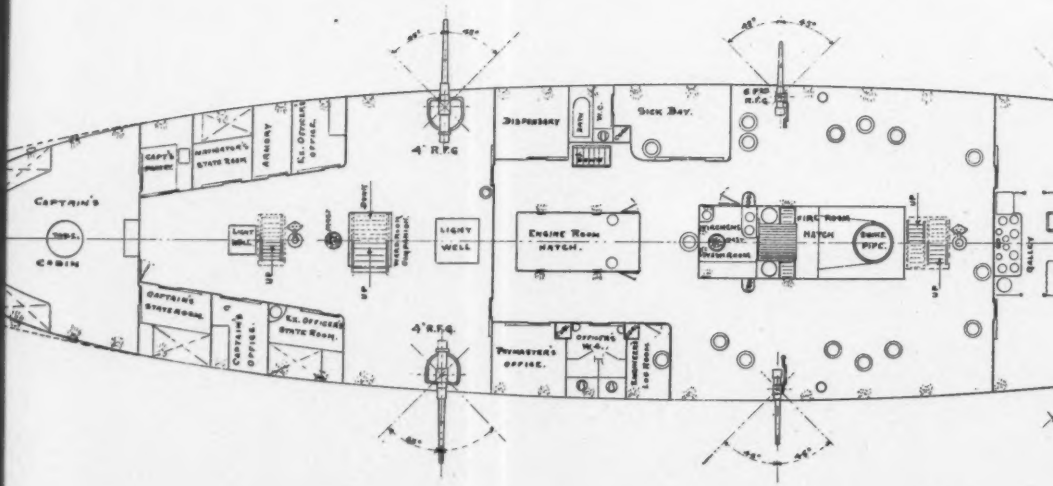
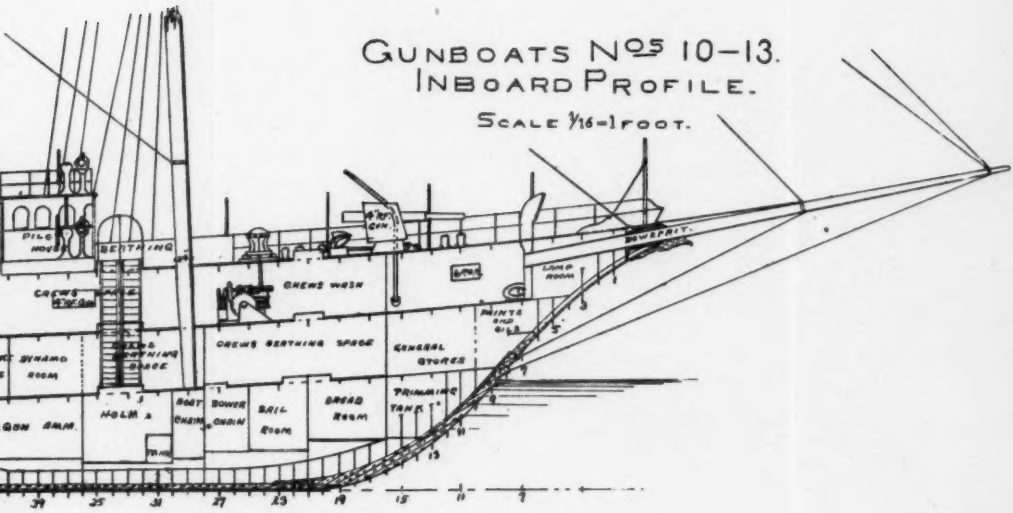
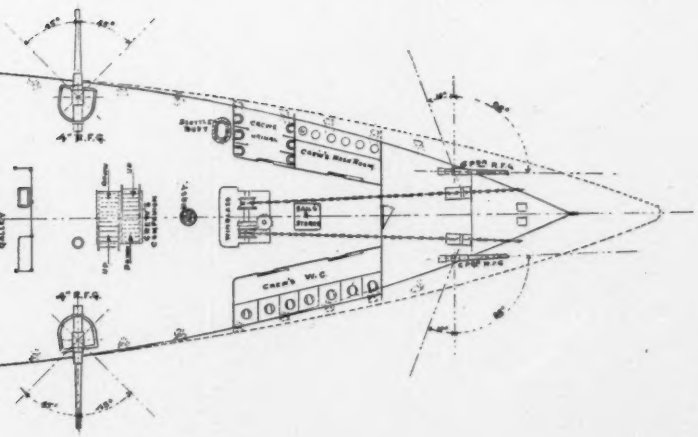
55
51
47
43


4" R.F.G.
DISPENSARY
SICK BAY.
CAPTAIN'S CABIN
ENGINE ROOM HATCH.
LIGHT WELL
FIRE ROOM HATCH
4" R.F.G.
PAYMASTER'S OFFICE.
GALLEY

GUNBOATS NOS 10–13.
INBOARD PROFILE.

SCALE 1/16–1 FOOT.





lis crossed the line at 9 hours 4.5 seconds, and the end buoy at 10 hours 48 minutes 51 seconds A. M.; on the return run, crossed the line at 10 hours 58 minutes 19.5 seconds, and finished at 12 hours 43 minutes 52 seconds. The total elapsed time was 3 hours 34 minutes 19 seconds. The mean corrected speed was 13.172 knots. There was very little vibration of the vessel. The main and auxiliary engines worked without a heated bearing. The boilers steamed freely, the water being at a steady height in the glasses during the trial. The fire room, in open communication with the engine room, was unusually comfortable.

The coal used was Pocahontas, run of mine, and Cardiff. The latter was stored in bags, and was used exclusively on the second run, 6,300 pounds being burned on that run.

CONTRACT TRIAL DATA.

Draught of water, beginning of trial, forward, feet and inches	11–5
aft, feet and inches	11–6
end of trial, forward, feet and inches	11–3
aft, feet and inches	11–6½
mean, forward, feet and inches	11–4
aft, feet and inches	11–6¼
average on trial, feet and inches	11–5⅜
Displacement (mean), tons	943
Area of immersed midship section, square feet	333
Wetted surface, square feet	6,980
Speed, mean, knots	13.172
Slip, per cent	17.3
Speed^3 × area immersed midship section ÷ I.H.P. (*A*)	622.49
Speed^3 × displacement$^{\frac{2}{3}}$ ÷ I.H.P. (*A*)	179.76
I.H.P. (*A*) per 100 square feet wetted surface	17.51

SYNOPSIS OF STEAM LOG.

Revolutions main engine, per minute	146.76
Piston speed, feet per minute	684.88
Steam pressure, in boilers, per gauge	224.7
at engine, per gauge	217.4
1st receiver, absolute	94.1
2d receiver, absolute	32.7
Vacuum in condenser, inches	24
Throttle valve opening	wide.
Double strokes of air pump, per minute	64.1
circulating pump per minute	291
feed pump, per minute	43.3

Temperature in degrees Fahrenheit:	
Injection	44
Discharge	78.5
Feed	110.7
Fire room	90
Air pressure in ash pits, inch of water	.9
Revolutions of forced draft blowers, average, per minute	397.7
Mean pressure in cylinders, H.P.	87.85
I.P.	42.6
L.P.	18.48
Aggregate equivalent pressure referred to L.P. piston	46.47
I.H.P.:	
H.P. cylinder	314.11
I.P. cylinder	413.02
L.P. cylinder	480.46
Collective, main engine	1,207.59
Air pump	1.86
Circulating pump	5.90
Main feed pump	7.21
Two forced draft blowers	4.64
Collective, main engine, air and circulating pumps (*A*)	1,222.56
Total all machinery in use	1,227.20
Indicated thrust (main engines only), pounds	24,685
per square foot of developed blade area, pounds	822.8
inch of thrust bearing	39.53
Cubic feet swept per minute by L.P. piston per I.H.P.	4.93
Square feet cooling surface per I.H.P. (*A*)	1.02
of H.S. per total I.H.P.	2.95
I.H.P. per square foot grate surface, total	12.52
heating surface, total	.34
ton machinery (penalty weight)	9.35

ROTARY *vs.* RECIPROCATING MARINE ENGINES.

THE RELATIVE ADVANTAGES AND DISADVANTAGES OF ROTARY AND RECIPROCATING ENGINES AS APPLIED TO SHIP PROPULSION.

By The Hon. Charles Algernon Parsons, Member.

[Read at the Institution of Civil Engineers. Engineering Conference.]

The advantages of a rotary motor for the purpose of marine propulsion are manifest as regards a direct application of the force of the steam to the shaft to be driven, and a consequent saving of bulk, weight, friction and wear.

When such a motor is shown to be economical in steam consumption, and that the power delivered by the motor at a high speed of rotation can be economically transformed into thrust power by the screw propeller, and that the whole of the machinery is simple and easy to work, the position of the rotary motor becomes well established as a rival of the reciprocating engine, provided there are no drawbacks to detract from the advantages which it manifestly possesses. Up to the present no such drawbacks have shown themselves, or seem likely to do so.

The compound steam turbine consists of a series of steam turbines set one after the other on the same axis, so that each turbine takes steam from the preceding one and passes it on to the succeeding one. Each turbine of the set consists of a ring of fixed blades called guides fixed to the casing, and also of a ring of moving blades attached to the shaft. The steam from the steam pipe entering all round the shaft passes through the first set of guides, then through the first set of moving blades, then through the second set of guides, then through a second set of moving blades, and so on through the complete turbine motor.

The blades are carefully shaped as in water turbines, and the

action of the steam in each turbine of the set is similar to that of water in the water turbine.

Steam is, however, an expansive fluid, and though its action in each individual turbine is approximately as if the fluid was inelastic, yet a small increment of volume takes place at each passage through the blades, and the expansion going on at something like geometric ratio at each of the numerous successive turbines soon assumes large proportions. Ratios of expansion of fifty up to one hundred or even two hundred fold are common in one single compound turbine of the condensing type—a notable feature in turbine practice being that high expansion ratios and very large volumes can be economically dealt with without necessarily increasing the size and weight of the engine to any large extent, or what is perhaps more important and gives the turbine a special advantage over ordinary engines, is that practically no increase in frictional resistances is incurred by arranging for the extra expansion, and exceptional economy in steam is thereby realized.

The high speed of revolution diminishes not only the weight of the engines themselves in proportion to a given horse power, but also of the shafting, propellers and supports, as well as of the hull. The total weight of machinery in vessels of the torpedo boat or torpedo boat destroyer class on the turbine system, will probably not exceed one-third that of ordinary engines of the same power.

The consumption of steam on recent trials on the *Turbinia* has been shown not to exceed 14½ pounds per indicated horse power at full load, or considerably less than that of similar engines of the reciprocating class, so that the size and weight of the boilers, and also the amount of coal carried, can be considerably reduced, and consequently the total displacement of the vessel to be propelled will be largely reduced, so that with a given horse power much greater speeds may be attained, or, on the other hand, heavier cargoes may be carried with a given consumption of coal per knot.

To these advantages must be added that the space occupied by the turbines is very much less than that occupied by ordinary

engines, thus increasing the capacity of the vessel, and also that the turbine machinery being placed near the bottom of the vessel, the center of gravity is thereby lowered, and the stability of the vessel increased. Also, owing to their position (and even in the *Turbinia* with only three feet draught), they lie almost wholly below the water line—a matter of considerable importance in war vessels.

The almost total absence of vibration, owing to there being no reciprocating parts, admits of a diminution in the weight of the hull, and in fast vessels admits of a degree of comfort not hitherto attainable, and also in the case of warships, enables guns and torpedoes to be worked with ease and accuracy.

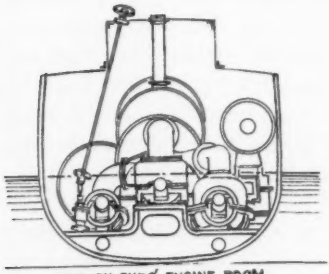
Another feature is that owing to the reduced size and weight of the shafts and propellers, this not only facilitates duplication and repair, and enables spare parts to be carried on board the vessel to an extent not hitherto practicable, but also, owing to the smaller diameter of the propellers, it admits of screw-propelled vessels being used for navigating shallower waters.

To summarize, the merits of the turbine system applied to marine propulsion appear to be:

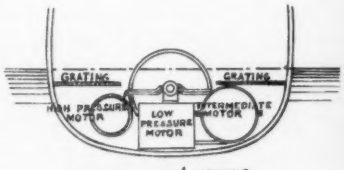
1. Greatly increased speed, owing to diminution of weight and smaller steam consumption.
2. Increased carrying power of vessel.
3. Increased economy in coal consumption.
4. Increased facilities for navigating shallow waters.
5. Increased stability of vessel.
6. Reduced weight of machinery.
7. Reduced cost of attendance on machinery.
8. Reduced size and weight of screw propellers and shafting.
9. Absence of vibration.
10. Lowered center of gravity of machinery, and reduced risk in time of war.

The first ship fitted with turbine engines has been the *Turbinia*. She is 100 feet in length, 9 feet beam, 3 feet draught amidships, and 44½ tons displacement. She has three screw shafts, each directly driven by a compound steam turbine of the parallel flow type. The three turbines are in series, and the steam is expanded

(at full power) from a pressure of 170 pounds absolute, at which it reaches the motor, to a pressure of 1 pound absolute, at which it is condensed. The shafts are slightly inclined, and each carries three screws, making nine in all. The screws have a diameter of 18 inches, and when running at full speed they make



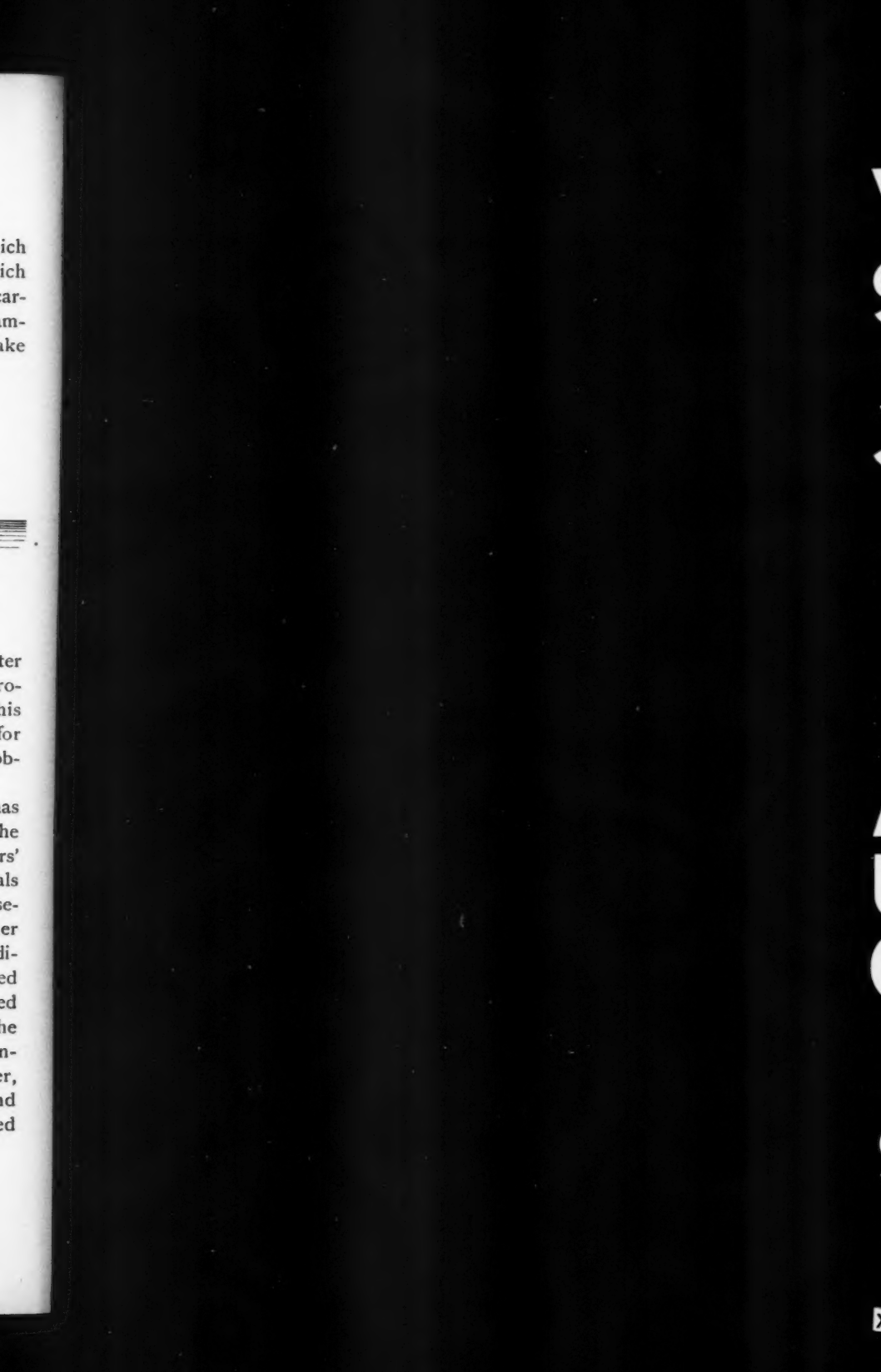
SECTION THRO' ENGINE ROOM LOOKING AFT.



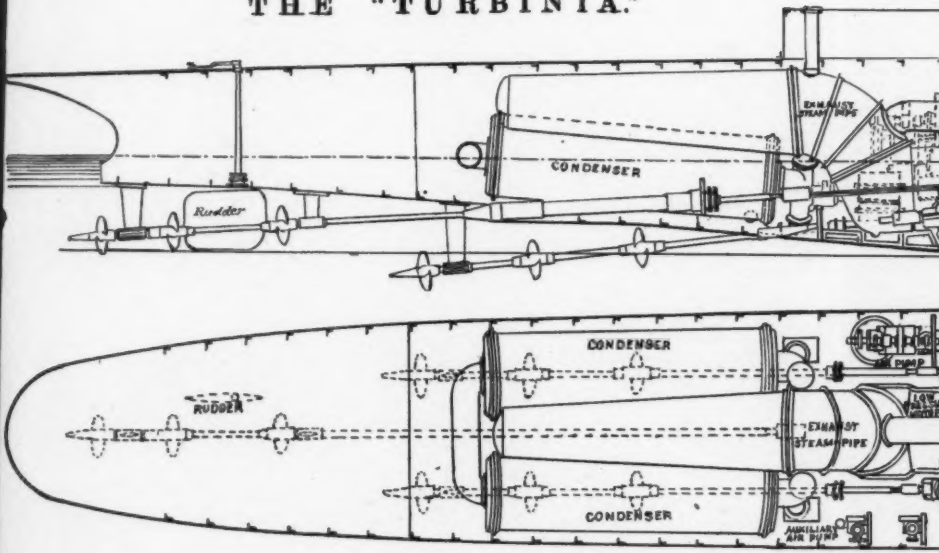
SECTION THRO' MOTORS.

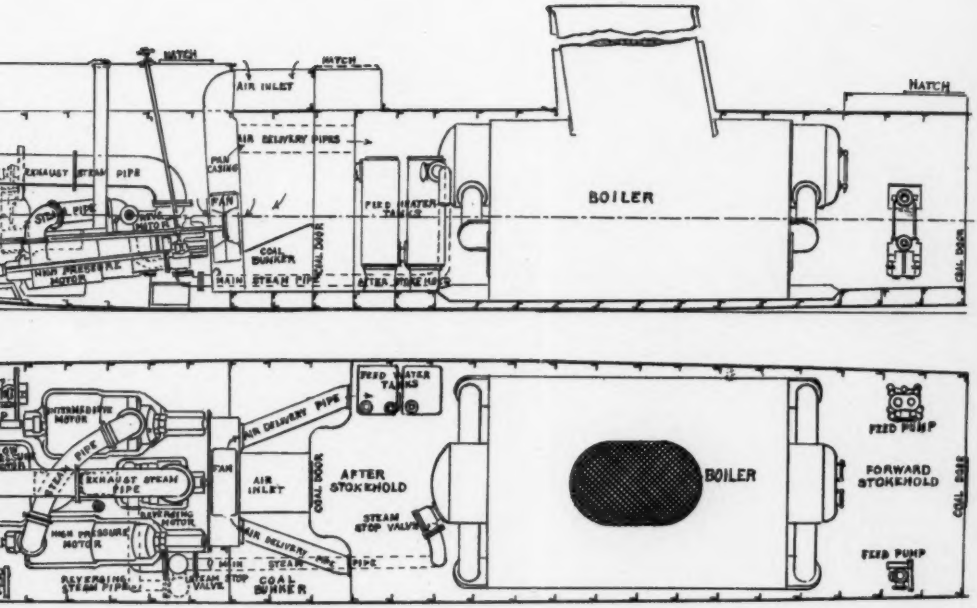
2,200 revolutions per minute. Steam is supplied from a water tube boiler, and the draft is forced by a fan, mounted on a prolongation of the low pressure motor shaft, the advantage of this arrangement being that the draft is increased as the demand for steam increases, and also that the power to drive the fan is obtained directly from the main engines.

Up to the present, the maximum mean speed attained has been $32\frac{3}{4}$ knots, as the mean of two consecutive runs on the measured mile. These runs were made after about four hours' steaming at other speeds, and the boat on the day of the trials had been 15 days in the water. It is anticipated that on subsequent trials, after some alterations to the steam pipe, still higher mean speeds will be obtained. As it stands, however, the indicated horse power realized is 2,100, and the consumption of feed water per indicated horse power hour, $14\frac{1}{2}$ pounds, and the speed the fastest of any vessel irrespective of size. The weight of the main engines is 3 tons 13 cwt. Total weight of machinery, including turbines and auxiliary engines, condenser and boiler, the propellers and shafts, the tanks and the water in boiler and hot well, 22 tons. Thus nearly 100 horse power is developed



THE "TURBINIA."




HATCH
AIR INLET
HATCH
HATCH
AIR DELIVERY PIPES
FAN CASING
EXHAUST STEAM PIPE
STEAM PIPE
DRIVING MOTOR
FAN
HIGH PRESSURE MOTOR
COAL BUNKER
MAIN STEAM PIPE
COAL DOOR
EXTRA STEAM PIPES
FEED HEATER TANKS
BOILER
COAL DOOR

INTERMEDIATE MOTOR
STEAM PIPE
EXHAUST STEAM PIPE
REVERSING MOTOR
HIGH PRESSURE MOTOR
REVERSING STEAM PIPES
FAN
AIR INLET
AIR DELIVERY PIPE
COAL DOOR
FEED WATER TANKS
AFTER STOKEHOLD
STEAM STOP VALVE
AIR DELIVERY PIPE
MAIN STEAM PIPE
STEAM STOP VALVE
COAL BURNER
BOILER
FEED PUMP
FORWARD STOKEHOLD
COAL BUNK
FEED PUMP

per ton of machinery, and nearly 50 horse power per ton of displacement of boat.

In the *Turbinia*, the stresses on the boiler and machinery are, as far as possible, according to Board of Trade rules, and the scantlings of the hull are heavy for a boat of her size and class.

It is believed that when boats of 200 feet in length and upwards are fitted with compound turbine motors, speeds of 35 to 40 knots may be easily obtained in vessels of the destroyer class, and it is also believed that the turbine will—in a lesser degree—enable higher speeds to be realized in all classes of passenger vessels.

CONTRACT TRIAL OF THE U. S. S. *NASHVILLE*.

By Passed Assistant Engineers W. Strother Smith and C. B. Price, U. S. Navy.

The steel, twin screw gunboat *Nashville* is the third vessel built by the Newport News Shipbuilding and Dry Dock Co. for the U. S. Navy. Her keel was laid at the works in Newport News, Va., on August 9, 1894, and she was launched on October 19, 1895. The designs and specifications were furnished by the Navy Department, and the vessel was contracted for at $280,000, complete with furnishings and equipment, the armament only being excepted.

She has a flush upper deck, covering the main deck from stem to stern. On this deck, a part of the main battery is arranged to command a large angle of fire. The boats, with the exception of the gig and whaleboats, are carried on a skid beam running athwartship and between the smoke pipes.

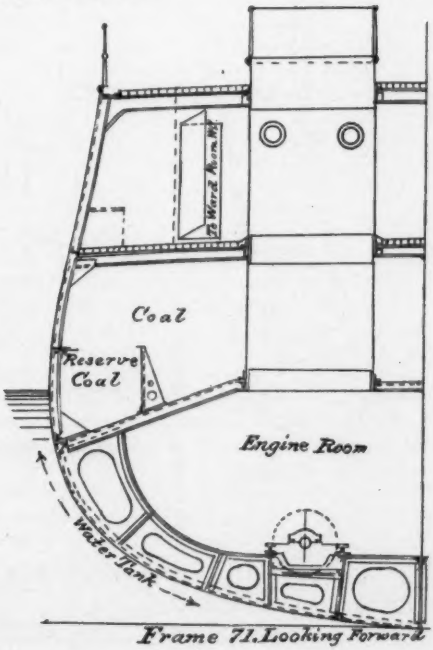
The main deck is well ventilated by the hatches and gun ports, and affords protection to the crew in wet weather, with room for drill and exercise. The cabin, wardroom, offices, pantries and galley are all on this deck.

Forward on the berth deck are the sick bay, dispensary and additional berthing space for the crew. Amidship are the upper bunkers on each side, outboard and abreast of the machinery spaces, while between these are the boiler hatches, uptakes, wash rooms, machine shop, dynamo room and engine hatches. Around and between these spaces is a passage way leading fore and aft. Abaft the engine hatches is the space fitted for the machinists' and petty officers' quarters, and in the next compartment are two wardroom staterooms, wardroom bath and store rooms.

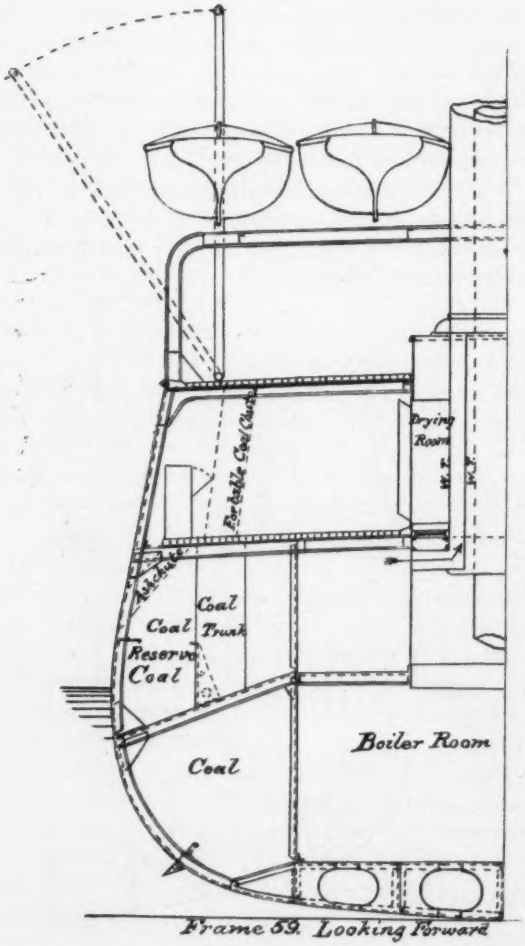
Below the berth deck are the magazines and store rooms, forward and aft of the machinery space.

There are nine boats: a 30-foot steam cutter, a 30-foot sailing cutter, two 28-foot cutters and one dinghy, carried on the upper deck; and two 29-foot whaleboats, one of which is fitted up as a gig, carried on davits, on one set abreast the engine room hatch at sea, and on a set further aft in port.

The main battery consists of eight 4-inch rapid fire rifles, four on the main deck in sponsons and four on the upper deck, two forward and two aft. The guns on the upper deck are protected by shields and those on the main deck, by sponson armor of $2\frac{1}{4}$-inch nickel steel. There are four 6-pounder rapid fire guns in sponsons on the main deck, two well forward and two in the cabin. There are also two 1-pounders and two Gatling guns on carriages for boat or landing service. It was originally intended to fit this vessel with torpedoes, but they have been omitted in the course of construction.



There is a double bottom under the machinery space, which is worked only partially under the lower bunkers, but carried up to the water tight deck in the engine space, the two outboard longitudinal spaces being used as fresh water tanks to make up



Frame 59. Looking Forward

boiler feed. Coal protection is provided by working a fore-and-aft partial bulkhead in the upper bunkers from the water tight deck to above the water line, thus forming an open pocket for reserve coal.

The contract required an average speed of 14 knots for four consecutive hours, subject to a penalty at the rate of $20,000 per knot, with a corresponding premium for any excess. After the contract was made, it was decided to increase the beam from 36 to 38 feet, and a specified sum was allowed for this increase, as the original speed of 14 knots was adhered to. While the bonus obtained was calculated on the basis of 14 knots, any comparison of speed with other vessels should be based on a speed of 13.75 knots.

HULL.

Length between perpendiculars, feet	220
on L.W.L., feet and inches	221–5
over all, feet and inches	233–8
Beam, feet	38
Ratio of length to beam	5.79
Depth of hold, top of floors to top of main deck beams, feet and inches	15–10$\frac{3}{4}$
Draught, mean, seagoing trim (normal), feet	11
Trim, by the stern, inches	7$\frac{5}{8}$
Displacement (normal), tons	1,372.35
Tons per inch L.W.L.	13.16
Area of immersed midship section L.W.L., square feet	370.05
L.W.L. plane, square feet	5.526.62
Center of gravity of L.W.L. abaft midship section, frame No. 54, feet and inches	1–10$\frac{5}{32}$
Center of gravity above bottom of keel, feet and inches	13– 3$\frac{1}{16}$
Center of buoyancy above bottom of keel, feet and inches	6– 4$\frac{13}{32}$
aft of midship section, frame No. 54, feet and inches,	2– 4$\frac{1}{16}$
Transverse metacenter above center of buoyancy, feet and inches	9– 8$\frac{1}{4}$
Longitudinal metacenter above center of buoyancy, feet	267
Transverse G.M., metacentric height, feet and inches	2– 9$\frac{5}{32}$
Longitudinal G.M., feet and inches	260– 1$\frac{11}{32}$
Block coefficient for displacement	.518
Cylindrical coefficient for displacement, longitudinal cylinder	.587
Midship section coefficient	.882
L.W.L. coefficient	.659
Wetted surface to L.W.L., square feet	8.221
Number of frames	109
water tight compartments below main deck and including double bottoms	53

MAIN ENGINES.

They are twin screw engines of the vertical, inverted, direct-acting, four-cylinder, quadruple expansion type and were designed by the Navy Department. They are placed in one compartment with their auxiliaries, and the design is a marked departure from the usual arrangement. The L.P. cylinders are placed forward, the H.P. cylinders being aft; the cranks are 90 degrees apart and follow in regular order, the H.P. crank in the lead. The 2d I.P. crank shaft is connected to the L.P. crank shaft by means of a disconnecting coupling. The air pump is worked by a rock shaft and beams connected to the 2d I.P. crosshead, and the exhaust of that cylinder is arranged to go into the third receiver or directly to the condenser. The L.P. engine may be disconnected and the propelling engines made triple expansion.

The cylinders are steam jacketed and fitted with the usual reducing valves and traps. They are also well lagged with magnesia and wood covering. Each H.P. cylinder has one, and each 1st I.P., two piston valves; each 2d I.P. and each L.P. cylinder has one double-ported slide valve, provided with a balance cylinder, the top of which connects with the condenser. The valve gear is of the ordinary Stephenson link motion with double bar links.

The main engines were designed to run at 300 revolutions per minute with a steam pressure of 250 pounds per square inch on the main boilers and 160 on the auxiliary boilers.

The framing of the engines consists of wrought steel columns tied with wrought steel ties, and supports the cylinders from a cast steel bed plate, made in four sections and bolted together. The columns support the cast iron guides for the crosshead slippers, which are of manganese bronze. The piston rods and valve stems are made of wrought steel, oil-tempered and ground to true cylinders. The crank shafts are in three sections of different lengths. The condenser for each engine is placed outboard.

The following are some of the principal dimensions of the main engines.

DATA OF ONE MAIN ENGINE (STARBOARD).

Number of cylinders		4
Diameter of cylinders, inches	H.P.	11
	1st I.P.	17
	2d I.P.	24
	L.P.	34
Stroke, inches		18
Diameter of valves, inches	(one) H.P. and 1st I.P. (two)	6
Width and height of 2d I.P. valve, inches		26 × 23$\frac{61}{64}$
L.P. valve, inches		37 × 24$\frac{13}{64}$
Diameter of piston rods (all), inches		3
Length of connecting rods, center to center, inches		40
Volume swept by pistons per stroke, mean, cubic feet	H.P.	.99
	1st I.P.	2.36
	2d I.P.	4.92
	L.P.	9.48
Volumetric cylinder clearance (mean of the two ends), cu. ft.,	H.P.	.309
	1st I.P.	.646
	2d I.P.	.643
	L.P.	.948
Ratios of net areas of pistons	H.P. to 1st I.P.	2.46
	2d I.P. to L.P.	2.017
	H.P. to L.P.	10.001
	H.P. to 2d I.P.	4.956
	2d I.P. to 1st I.P.	2.015
Crank shaft, length, H.P. section, feet and inches		3–10$\frac{5}{8}$
both I.P. cranks, one section, feet and inches		7– 0$\frac{1}{2}$
L.P. section		3–11$\frac{5}{8}$
diameter, inches		6$\frac{1}{4}$
axial hole, diameter, inches		3$\frac{1}{2}$
Crank pins, diameter, inches		6$\frac{3}{4}$
length, inches		7$\frac{1}{2}$
axial hole, diameter, inches		3$\frac{1}{2}$
Propeller shafts, forward section, length, feet and inches		18–10$\frac{3}{4}$
after section, length, feet and inches		27– 3$\frac{1}{2}$
diameter and axial hole, inches		6$\frac{1}{8}$– 3
Thrust shaft, diameter, inches		5$\frac{7}{8}$
axial hole, inches		2$\frac{7}{8}$
length, feet and inches		12– 7
number of thrust collars		9
thickness of thrust collars, inches		1$\frac{1}{8}$
diameter of thrust collars, inches		8$\frac{1}{2}$
thrust surface of collars, square inches		310.08

PROPELLERS.

The propellers are three-bladed, with adjustable pitch, the boss and blades being of manganese bronze. The starboard propeller

is right, and the port one left-handed. The pitch is that of a true screw, and the blades are set back at a slight angle, the edge of the periphery being 3 inches from the perpendicular.

DATA OF ONE PROPELLER.

Number of blades	3
Diameter, feet and inches	6–8
of hub, feet and and inches	1–8
Length of hub, feet and inches	1–6
Helicoidal area, square feet	13.02
Disc area, square feet	34.8
Pitch, as set, feet	7
Ratio of pitch to diameter	1.05 to 1
Distance of center of hub above lowest point of keel, feet and inches	4–0$\frac{13}{16}$

CONDENSERS.

There are two main condensers of the cylindrical type. The shells are of cast composition, made in two sections and bolted together. The circulating water passes through the tubes.

Diameter of shell, inside, feet	3
Number of tubes in one condenser	946
Length between tube sheets, feet	8
Diameter of tubes, outside, inch	$\frac{5}{8}$
Cooling surface, one condenser, square feet	1,238.3
Ratio total cooling surface to total H.S.	1 to 2.16

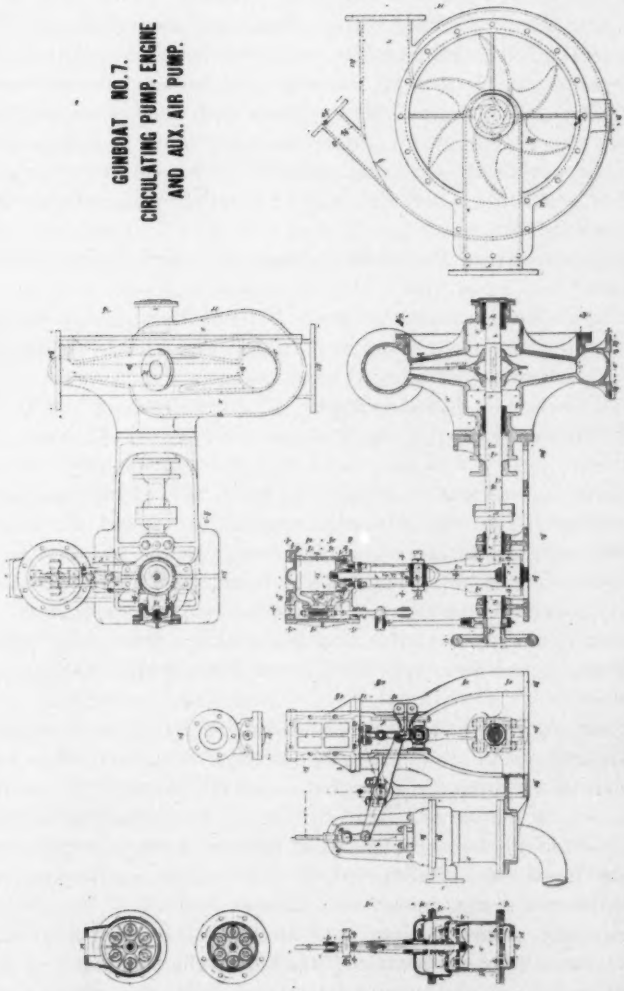
Air Pump.—There is an air pump for each engine, driven by a rock shaft and arms from the second I.P. crosshead. These pumps are of the same design and general measurements as those on the *Helena* and *Wilmington*, a description and cut of which were given in the preceding number of this JOURNAL.

Centrifugal Pumps.—There are two, double inlet, centrifugal pumps situated in the forward end of the engine room, one on either side. The diameter of the runner is 22, of the suction 7, and of the discharge, 6 inches. They are fitted to draw from the sea, from the main drain, and from the engine room bilge, and to deliver to the condenser, and by means of a by-pass valve and connecting pipe, directly overboard. There is also a small discharge nozzle to which is connected the water service pipe.

Each pump is driven by a single vertical engine, with a cylinder 6 inches in diameter and a stroke of 5 inches. The diameter of the piston rod is 1$\frac{3}{8}$ inches.

No auxiliary condenser is fitted, it being the intention to use either of the main condensers for auxiliary purposes. To this

GUNBOAT NO. 7.
CIRCULATING PUMP, ENGINE AND AUX. AIR PUMP.



end, each circulating pump engine drives an auxiliary air pump connected by arms and a rock shaft to its crosshead, as shown in the cut.

These pumps are fitted with the necessary connections to their condensers, and assist the main air pumps when the engines are in operation. They are of the same general design as the main air pumps, but there is only one valve each for the suction, delivery and pump bucket; these valves are annular in shape and are concentric with the pump cylinder. The cut shows a number of small valves, but this was changed to one valve as just described.

The diameter of the pump cylinder is 6, and the stroke is 4 inches.

Feed and other Auxiliary Pumps.—All of the auxiliary pumps are of the Blake vertical duplex pattern. There are in the engine room two main feed pumps, steam cylinder, 7, and water cylinder, 4 inches in diameter, stroke, 7 inches; one fire and bilge pump, steam cylinder, $7\frac{1}{2}$, and water cylinder, $4\frac{1}{2}$ inches in diameter, stroke, 8 inches; one bilge and sanitary pump, steam cylinder, 6, and water cylinder, 4 inches in diameter, stroke, 7 inches; and one distiller pump, combined fresh and salt water, steam cylinder, $3\frac{1}{2}$, and water cylinders (2), $2\frac{1}{8}$ inches in diameter, stroke, 4 inches. In each fire room there is an auxiliary feed pump, one with steam cylinder, 6, and water cylinder, 4 inches in diameter, stroke, 7 inches, and the other with steam cylinder, 8, and water cylinder, $4\frac{1}{2}$ inches in diameter, and stroke, 8 inches.

Distilling Apparatus.—This consists of a Baird No. 4, type B evaporator with U tubes, the plane of the U being horizontal and the steam escaping by a single tube at the bottom. There are two No. $2\frac{1}{2}$, double coil Baird distillers. A detailed test of this evaporator is given on page 95 of Volume VIII, in a paper by Chief Engineer G. W. Baird, U. S. Navy. The water was good and the final test complied with the specifications.

A double connection was made to the shell by the contractors to allow an easy escape of the steam from the evaporator to the distillers.

There is a vertical combined salt and fresh water pump for feeding the evaporator and pumping the fresh water from the filter. The steam cylinder is $3\frac{1}{2}$ inches, and the water cylinders $2\frac{1}{8}$ inches in diameter, the stroke being 4 inches.

Ash Hoists.—There are two ash hoists, one for the main boilers and one for the auxiliary boilers. They are single cylinder, direct-pull engines; that for the main boilers has a movable block, and that for the auxiliary boilers, a single direct pull, both hoisting by means of a continuous wire rope. There is a See ejector in the main boiler fire room.

Forced Draft.—The forced draft is supplied by three Sturtevant blowers; one 48-inch fan in the after fire room for the Scotch boilers, and two 36-inch fans in the forward fire room for the Yarrow boilers. The fans take air from the fire room and discharge it into ducts leading to the ash pits.

The fans are driven by enclosed double engines, with cranks at 180°. The diameter of the cylinders for the 48-inch fan is 4 inches, and the stroke, 3 inches, and for the 36-inch fans, $3\frac{1}{2}$ inches, with a stroke of $2\frac{1}{2}$ inches.

Electric Plant.—The lighting installation consists of 240 incandescent lamps, one search light and one set of signaling apparatus. There are seven electric mains supplied by seven feeders. All the wires running throughout the engine and fire rooms are protected by iron tubing made water and steam tight.

There are two Navy standard generating sets, one 8-kilowatt and one 16-kilowatt, 80 volts, of the compound-wound, quadripolar, direct-connected type, built by the General Electric Co. Both dynamos are driven by double vertical engines, the cylinders of the 8-kilowatt dynamo being $6\frac{1}{2}$, and those of the 16-kilowatt dynamo, $8\frac{1}{2}$ inches in diameter. The stroke of both engines is 5 inches.

Ventilation.—Artificial ventilation is provided on the berth deck and all below by means of seven electrically-driven fans made by the B. F. Sturtevant Co. All above the berth deck is to be ventilated by the open hatches and air ports. There are two blowers forward of bulkhead 33; the one on the starboard side is arranged for both supply and exhaust, and the one on the

port side, for exhaust only. There are two blowers on the starboard side abreast of the after boiler hatch, both supply, and they serve their own compartment and the one just forward. The next two are in the petty officers' quarters, one on each side, and exhaust only. They draw from the quarters aft and deliver into the engine room. The remaining one is situated in the steering engine room and supplies its own and adjacent compartments with air.

All but one of these blowers are worked by 2-kilowatt motors, the exception having a 3-kilowatt motor.

Feed Regulator.—Each of the four Yarrow boilers has an automatic feed regulator of the Thornycroft patent. It consists of a lever balanced near the middle, on one end of which is a float and on the other, a counterbalancing weight. A series of connections near the fulcrum actuates a small double poppet valve, through which the feed water enters the boiler. The height of the water is regulated by a connection on the outside controlling the motion of the balanced lever. When the water rises, the float is carried up and closes down the poppet valve, and vice versa when the water gets low. The feed pump is run continuously, slowing or starting as the need requires.

(A cut of this feed regulator will be published in the next number of the JOURNAL.—EDIT.)

MAIN BOILERS.

There are four main boilers of the Yarrow type, built by the contractors from their own designs.

The steam and water drains are of open-hearth steel, and the tubes, of copper.

The steam drum is cylindrical, made in halves, the two parts being held together by steel bolts. The joint is made of red lead and the flanges were planed true and grooved. The flanges are slightly beveled in every three spaces for "break joint" wedges. The water drums are made in practically the same manner as the steam drum, the lower half being cylindrical, and the upper half, which forms the tube plate, flat. The tubes are in nine rows, spaced zig-zag. In the bottom of each water drum

are five $2\frac{3}{4}$-inch × 4-inch hand holes, spaced 15 inches from center to center.

DATA FOR ONE BOILER.

Working pressure, pounds	250
Length over all, feet and inches	8–9
Width over flanges of water drums, feet and inches	7–5
Number of furnaces	1
Length of grate, feet and inches	6–8
Width of grate, feet and inches	3–9
Grate surface, square feet	25
Steam drum, length over heads, feet and inches	8–2
diameter, inside, inches	28
thickness of top, inch	$\frac{7}{16}$
bottom, (tube plate) inches	$1\frac{5}{16}$
thickness of head, inch	$\frac{9}{16}$
Water drums, inside radius, inches	$7\frac{1}{2}$
thickness, bottom, inch	$\frac{9}{16}$
top, (tube plate), inches	$1\frac{1}{2}$
Tubes, number, No. 13 B.W.G	730
diameter, outside, inches	$1\frac{5}{8}$
length, maximum, feet and inches	$4–2\frac{5}{8}$
minimum, feet and inches	4–1
Distance between tube plates, least, feet and inches	$3–9\frac{5}{16}$
center to center of tubes, longitudinally, inches	$2\frac{1}{8}$
diagonally, inches	$1\frac{7}{8}$
Heating surface, square feet	1,000
Ratio H.S. to G.S.	40

Test, No.	Diameter, outside, inches.	Thickness, inch.	Parting load, pounds.	Remarks.
1	$1\frac{1}{16}$	.095*	4,300	Very well expanded.
2	$1\frac{5}{16}$	$\frac{7}{64}$	4.000	Well expanded.
3	$1\frac{1}{2}$	$\frac{1}{16}$	2,800	Not well expanded.

*No. 13, B.W.G.

In this connection may be mentioned an experiment conducted by the contractors to determine the holding power of expanded copper tubes. There were three tests made under the following conditions: a copper tube was expanded by a drift pin into a

wrought iron flange, 1¼ inches thick, and the holding power determined by the weight required to pull the tube out of the flange. The tubes were not beaded over, but were filed off flush with the face of the flange, and the holes were smoothly bored.

The table on page 585 shows the results obtained.

AUXILIARY BOILERS.

For auxiliary purposes there are two single ended, horizontal, return fire tube boilers, with one furnace each. They are built of two courses of two sheets each, and the tops of the front and back heads are curved in the usual manner. These boilers are of steel, except the tubes, which are of charcoal iron, and are designed for a working pressure of 160 pounds per square inch. The usual mountings are fitted except the hydrokineter, instead of which there is a feed water circulator acting on the same principle as a suction tee. This fitting is placed in connection with the internal feed pipe and mixes the water from the bottom of the boiler with the entering feed.

DATA FOR ONE BOILER.

Shell, length over heads, feet and inches	9–10⅞
diameter, mean, feet and inches	7–6⅝
thickness, inch	11/16
Furnaces, number	1
diameter, least inside, inches	40
greatest inside, inches	42
thickness, inch	½
length of grate, inches	72
Tubes, number of ordinary, No. 10 B.W.G.	98
stay, No. 6 B.W.G.	30
diameter all tubes, outside, inches	2¼
length between tube sheets, inches	85½
center to center of tubes, vertically, inches	3½
horizontally, inches	3⅜
internal diameter, ordinary, inches	1.982
stay, inches	1.844
Thickness of tube sheets, inch	⅝
Thickness of heads, top, inch	11/16
bottom, inch	⅝
Tube heating surface, square feet	544.27
Plate heating surface, furnace, square feet	47
combustion chamber, square feet	83.74

Total heating surface, square feet	675.01
Grate surface, square feet	21
Ratio H.S. to G.S.	32.14
Area through tubes, square feet	2.66
Steam space, normal, cubic feet	40

TOTALS FOR TWO BOILERS.

Heating surface, square feet	1,350.02
Grate surface, square feet	42
Area through tubes, square feet	5.33
Volume steam space, cubic feet	80
Area water surface, square feet	126.4
Net area auxiliary smoke pipe, square feet	7.06

Coal Bunkers.—There are 16 bunkers as shown on the annexed plan, the total of which, based on 42 cubic feet to the ton, is 400 tons. The capacities as given are from measurements from the under side of the beams and exclusive of all other obstructions. The plan shows the arrangement of bunkers and their several capacities.

Weights.—The following are some of the principal weights.

One engine proper, inclusive of bed plate, framing, valve gear, valves, crank shafts, cylinders, hand gear, relief valves, reciprocating parts, receiver pipes, lagging and air pumps, tons	14.321
One main boiler (Yarrow), empty, without fittings, tons	4.171
One condenser, with main exhaust pipe, air pump suction and discharge, tons,	3.344
Fittings for one main boiler, tons	2.248
One auxiliary boiler (Scotch) empty, without fittings, tons	9.337
Fittings for one auxiliary boiler, lagging, tons	1.878
Water in one main boiler at steaming level, tons	1.384
auxiliary boiler (4 inches above connection), tons	5 464
Main circulating pump, engine, injection pipe and outboard delivery pipe (not including valves), tons	.893

THE TRIAL.

The official trial of the *Nashville* was run on the 14th day of May, 1897.

The vessel left the shipyard at 2 P. M. on Saturday, May 8, and, after adjusting compasses in Hampton Roads, left Old Point at 4.30 P. M. for Bridgeport, Conn. Before leaving the yard the L.P. cylinders were disconnected, and it was the intention

to make the run with the auxiliary boilers under natural draft. Just after leaving Old Point, it was found that the speed was too slow to permit of making the passage in the desired time and the blowers were put on the auxiliary boilers. The whole trip was made with about .8 inch of air pressure under the two Scotch boilers.

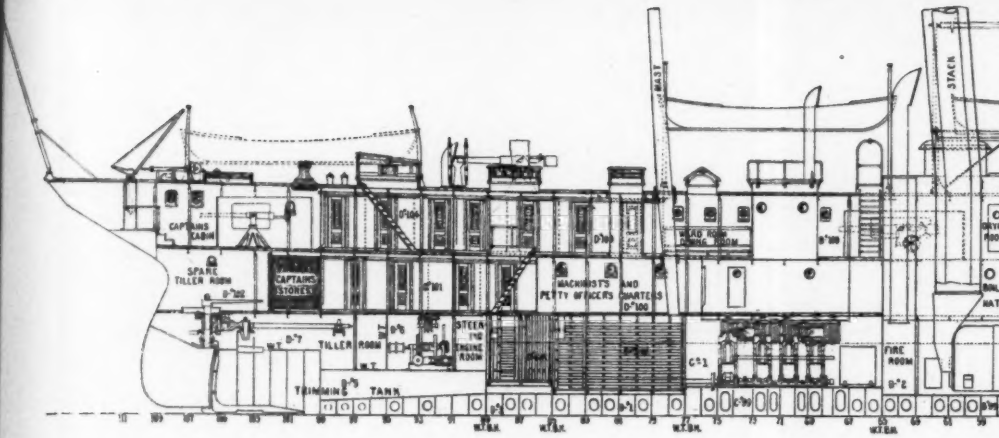
On Sunday, May 8, obse rvations were taken on the run from N. E. End Light Ship to Barnegat and a special report made, a resumé of which is attached after the trial trip data. The *Nashville* arrived at Bridgeport, Conn., about midnight on May 9th.

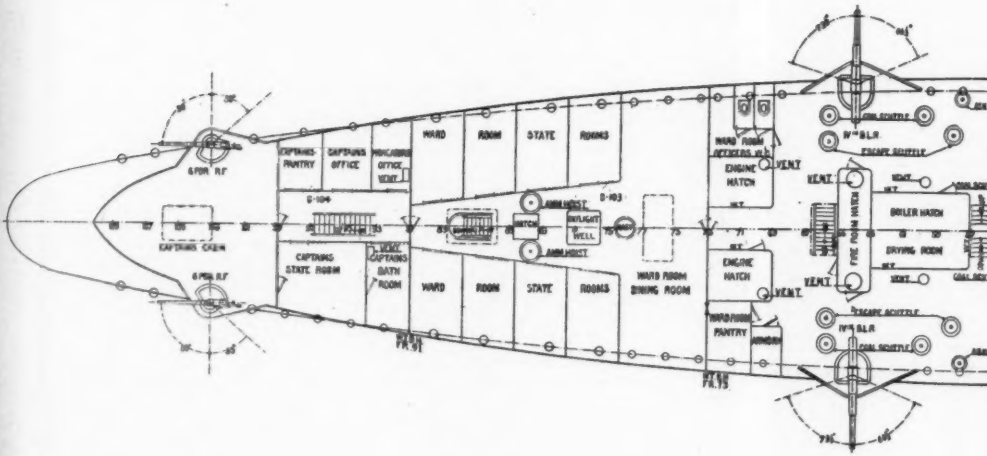
On the run from Cape Charles Light Ship to Scotland Light, the *Nashville* made an average speed of 10.63 knots. The sea was smooth to moderate and the wind was astern, with a force varying from 4 to 6. May 10th was spent in cleaning ship and making preparations. Tuesday, May 11, a trial run was made over a portion of the course. The trial course was laid off Stratford Shoal to a point a little to the westward of Horton's Point Light, the length being 30 nautical miles.

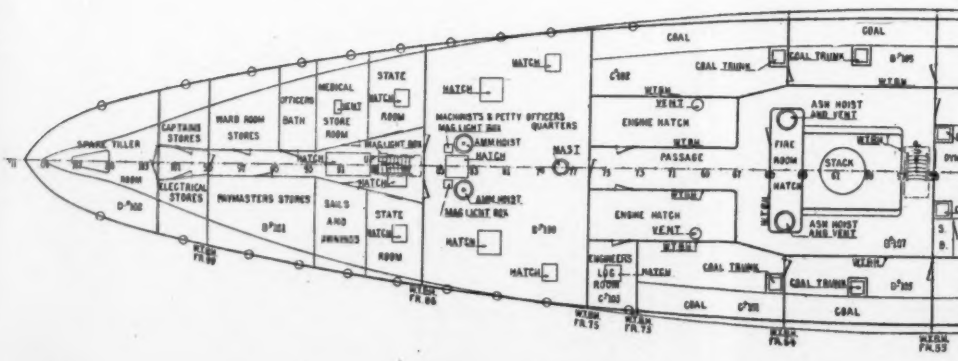
The official trial was made on Friday. The vessel started over the course at 1 hour 5 minutes 16.4 seconds P. M., and finished the first lap at 2 hours 52 minutes 29.4 seconds. She started back at 3 hours 6 minutes 52.9 seconds, and completed the trial run at 4 hours 55 minutes 9.4 seconds P. M. The total elapsed time was 3 hours 35 minutes 29.5 seconds, and the resultant speed without tidal corrections was 16.7 knots. For one division of the course, six nautical miles in length, a speed of 16.99 knots was attained. The final corrected speed, after making all tidal corrections, was 16.299 knots, giving the contractors a bonus of $45,980.

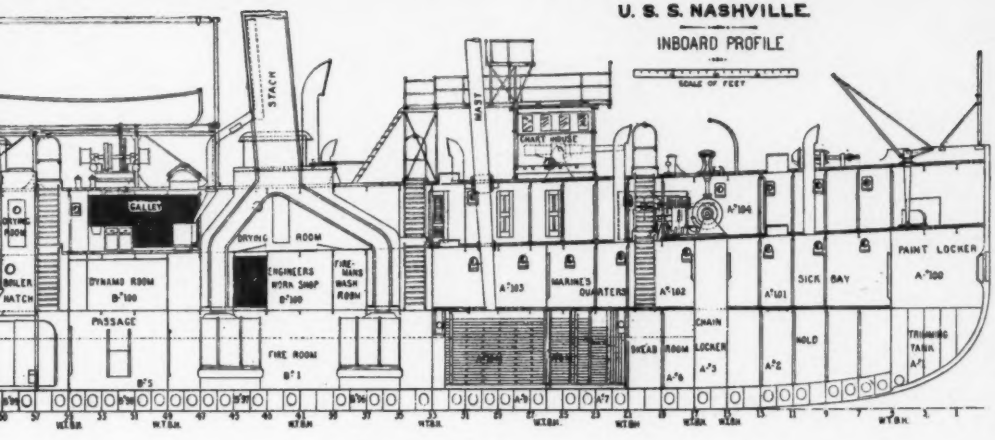
The trial passed off without a hitch of any kind, the engines were remarkably free from vibration, the bearings were cool without the use of water on them, and the boilers steamed steadily, the Yarrow boilers carrying steam almost as steadily as the Scotch type. Live steam was frequently admitted from the main steam pipe into the first receiver, and at times live steam was admitted also into the second receiver.

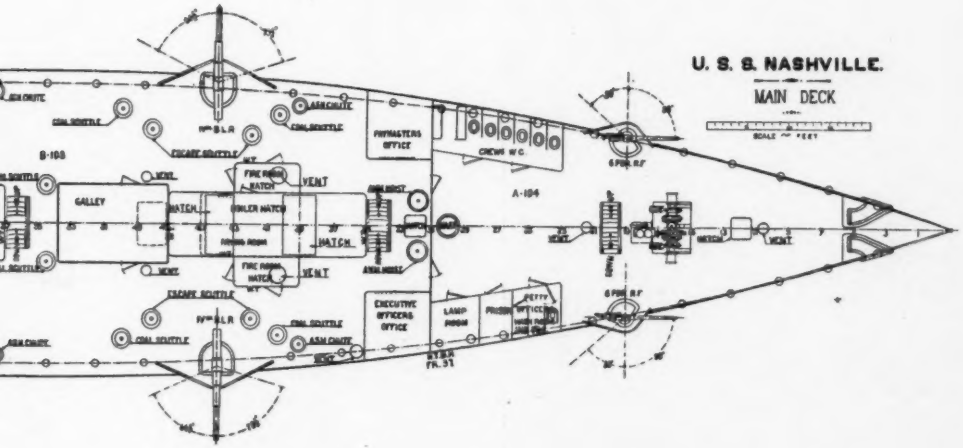
The coal used was picked Nuttalberg, put up in bags of a 112

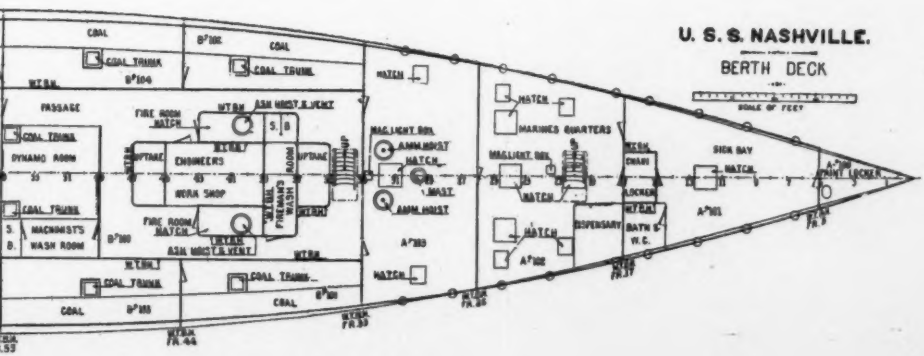

CAPTAINS CABIN
SPARE TILLER ROOM
CAPTAINS STORES
TILLER ROOM
STEERING ENGINE ROOM
TRIMMING TANK
MACHINISTS AND PETTY OFFICERS
MESS ROOM
MAST
STACK
FIRE ROOM
W.T.BK.


CAPTAINS CABIN
CAPTAINS PANTRY
CAPTAINS OFFICE
CAPTAINS STATE ROOM
CAPTAINS BATH ROOM
WARD ROOM STATE ROOMS
WARD ROOM DINING ROOM
WARD ROOM PANTRY
ENGINE HATCH
BOILER HATCH
FIRE ROOM HATCH
DRYING ROOM
VENT
FR.91
FR.75


SPARE TILLER
CAPTAINS STORES
WARD ROOM STORES
OFFICERS BATH
MEDICAL STORE ROOM
STATE ROOM
ELECTRICAL STORES
PAYMASTERS STORES
SAILS AND AWNINGS
MACHINISTS & PETTY OFFICERS QUARTERS
MAG LIGHT BOX
AMM HOIST
HATCH
MAST
COAL
COAL TRUNK
ENGINE HATCH
PASSAGE
FIRE ROOM
STACK
ASH HOIST AND VENT
ENGINEERS MESS ROOM
W.T.BK.
FR.99
FR.86
FR.75
FR.64
FR.53


U. S. S. NASHVILLE.
INBOARD PROFILE
SCALE OF FEET
STACK
MAST
CHART HOUSE
GALLEY
DRYING ROOM
ENGINEERS WORK SHOP
FIREMANS WASH ROOM
DYNAMO ROOM
PASSAGE
FIRE ROOM
MARINES QUARTERS
SICK BAY
PAINT LOCKER
CHAIN LOCKER
HOLD
TRIMMING TANK
BOILER HATCH


U. S. S. NASHVILLE.
MAIN DECK
SCALE OF FEET
GALLEY
HATCH
BOILER HATCH
FIRE ROOM HATCH
VENT
ASH HOIST
ESCAPE SCUTTLE
COAL SCUTTLE
ASH CHUTE
PAYMASTERS OFFICE
CREWS W.C.
EXECUTIVE OFFICERS OFFICE
LAMP ROOM
PRISON
PETTY OFFICERS
6 PDR. R.F.


U. S. S. NASHVILLE.
BERTH DECK
SCALE OF FEET
COAL
COAL TRUNK
PASSAGE
DYNAMO ROOM
ENGINEERS
WORK SHOP
FIRE ROOM HATCH
ASH HOIST & VENT
MACHINISTS
WASH ROOM
MAG. LIGHT BOX
MARINES QUARTERS
SICK BAY
CHAIN LOCKER
RESERVOIR
BATH & W.C.
HATCH

pounds net. The coal used on the trip to Bridgeport and return was selected New River steam coal.

The trial crew numbered 83 officers and men, including pilots and draftsmen. The engine room force, 44 in number, was directed by Chief Engineer J. A. Williams, connected with the Newport News Co., and was divided as follows: chief engineers, 2; engineers, 2; machinists (special), 4; oilers, 12; boiler makers, 2; water tenders, 3; firemen, 8; coal passers, 4; boys, 4; yeoman, 1, and storekeepers, 2. The water tenders and oilers were machinists who had worked on the erection of the machinery on board ship. There were 15 in the steward's department.

CONTRACT TRIAL DATA.

Draught of water, beginning of trial, forward, feet and inches	9–10½
aft, feet and inches	12– 2
end of trial, forward, feet and inches	9– 9
aft, feet and inches	12– 0
mean, forward, feet and inches	9– 9⅞
aft, feet and inches	12– 1
average on trial, feet and inches	10–11⅝
Displacement (mean), tons	1,364
Area of immersed midship section	370
Wetted surface, square feet	8,881
Speed, mean, knots	16.299
Slip (mean of both screws) per cent	23.5
$Speed^3 \times$ area immersed midship section $\div$ I.H.P. (*A*)	640.4
$Speed^3 \times displacement^{\frac{2}{3}} \div$ I.H.P. (*A*)	212.84
I.H.P. (*A*) per 100 square feet wetted surface	28.17

SYNOPSIS OF STEAM LOG.

	Starboard.	*Port.*
Revolutions of main engine, per minute	308.53	308.3
Piston speed, feet per minute	925.59	924.9
Steam pressure, in boilers, per gauge....Yarrow,	252	aux., 154
at engine, per gauge	249	249
1st receiver, absolute	146	144
2d receiver, absolute	72	73
3d reveiver, absolute	28	28
Vacuum in condenser, inches	25	25
Throttle valve opening	wide.	wide.
Double strokes of circulating pump, per minute	354	332
feed pump, per minute....main,	28.5	aux., 29.5

	Starboard.	*Port.*
Temperature in degrees Fahrenheit:		
Engine room	103	103
Injection	52	52
Discharge	116	112
Feed, in tank	136	136
Fire rooms	131	105
Air pressure in ducts, mean, inches of water	1.26	
Revolutions of forced draft blowers, average, per minute	662	
Mean pressure in cylinders, H.P.	71.95	77.18
1st I.P.	45.38	45.57
2d I.P.	26.82	26.87
L.P.	17.50	17.47
Aggregate equivalent pressure referred to L.P. piston	49.74	50.33
I.H.P.:		
H.P. cylinder	184.67	197.88
1st I.P. cylinder	275.23	288.64
2d I.P. cylinder	337.59	338.13
L.P. cylinder	444.11	422.14
Collective, main engine	1,241.60	1,246.79
Circulating pump	7.03	7.03
Three feed pumps	21.74	
Three forced draft blowers	9 54	
Other auxiliaries	2.12	
Collective, main engine and circulating pumps (*A*)	2.502.45	
Total all machinery in use	2,535.85	
Indicated thrust (main engine only), pounds	18,971	19,065
per sq. ft. of developed blade area, pounds	1,457.07	1,464.28
square inch of thrust bearing	6.06	6.09
Cubic feet swept per minute by L.P. piston per I.H.P.	4.68	4.66
Square feet cooling surface per I.H.P. (*A*)	.99	
of H.S. per total I.H.P.	2.11	
I.H.P. per square foot grate surface, total	17.86	
heating surface, total	.474	
ton machinery (penalty weight)	15.37	

Coal.—Kind and quality, Nuttalberg, hand-picked and bagged. Pounds per hour, 7,593; auxiliary boilers, 1,940, Yarrow, 5,653.

On the run from Newport News to Bridgeport, a trial was conducted by Passed Assistant Engineer W. Strother Smith, U. S. Navy, with the engines working triple expansion and the two Scotch boilers under forced draft. Valuable assistance was rendered by Mr. F. C. Palen, draftsman for the Newport News Co., and Mr. H. B. Gregory, attached to the office of the Inspector of Machinery. The following results were obtained.

Distance run during trial, nautical miles			51
Elapsed time, hours, minutes, seconds			4·33·16
Average speed, knots			11.199
Slip, per cent			10.24
Wind, points from ahead			16
force, navy standard			4 to 6
Steam pressure, average			114.6
		Starboard.	*Port.*
Revolutions, average		180.7	181.52
I.H.P., main engines	H.P.	66.61	67.36
	I.P.	49.21	49.15
	L.P.	93.41	95.12
total		209.23	211.63
collective, both engines		420.86	
all machinery in operation		448.61	
Coal per I.H.P., per hour		2.84	
consumed per hour, pounds		1,273.3	
Equivalent consumption, tons per day		13.687	

NOTE.—The wetted surface, given in the hull data on page 577, is that of the hull only, without appendages. In the trial data, the wetted surface of the appendages has been added.—EDIT.

NOTES.

DOUBLE-TEMPERING OF FORGED STEEL IN FRANCE.

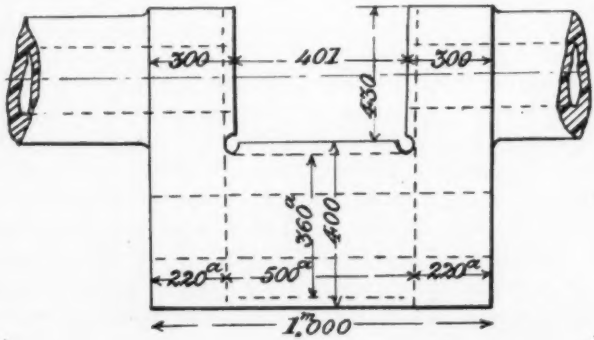
The JOURNAL is indebted to Assistant Engineer R. D. Hasbrouck, U. S. Navy, for the folllowing description and notes.

The process of double-tempering is used by the French Government for all pieces of forged steel which enter into the construction of a marine engine built in the Government shops. All cast steels are annealed.

In describing this operation, I will take as an example the double-tempering of the H.P. and I.P. crank shaft, in one piece, of the battleship *St. Louis*, at the Government machine shops at Indret.

The crank shaft in question had the following finished dimensions.

Diameter of shaft, inches	13.78
crank pins, inches	14.17
hole in pins and shaft, inches	5.91
Distance between centers, H.P. and I.P. cylinders, feet and inches	9–2.4
Length over all, feet and inches	16–0.3
of crank pins, inches	19.69
Width of webs, inches	17.32
Thickness of webs, inches	8.66



Getting the Shaft Ready for Tempering.—When the shaft comes from the forge it is taken to the lathe, and there turned down to within a few millimeters of the finished dimensions, and the axial holes bored. The crank pins are not turned up until after the tempering, although the holes are bored before. The cut shows one of the cranks before tempering and after being finished; the ordinary figures give the dimensions before tempering, and the indexed figures, the finished dimensions, all in millimeters. The dotted lines show the finished shaft, and the full lines, the shaft before tempering.

The process is divided into five operations.

(1.) The heat for the first tempering.

(2.) The first tempering.

(3.) Reheating for second tempering.

(4.) Partial cooling in the air.

(5.) Second tempering.

(1.) *The Heat for the First Tempering.*—The shaft is placed upon a truck, running on rails from the bath to the interior of the furnace; the platform of this truck is covered with fire brick and forms the bottom of the furnace when the truck is run inside. The shaft is carefully aligned on iron blocks, so that in heating it will not bend by its own weight. The furnace is of the ordinary reverberatory type and is heated several hours before the shaft is placed within it. The shaft in question was heated to a "cherry red," corresponding to a temperature of about 900° centigrade or 1,652° F. This took about twelve hours, as the heating should be gradual and as regular as possible. This temperature is judged entirely by the eye, and depends on the nature of the metal. For semi-hard steels, 800° to 900° centigrade, 1,472° to 1,652° F., seems to be the best temperature, and for soft steels, 900° to 1,000° centigrade, 1,652° to 1,832 F., and even more.

(2.) *First Plunge into the Bath.*—When the shaft was judged to be at the right temperature, the furnace doors were opened, and the truck was hauled, by means of a steam windlass and tackle, to the tempering tank, where a track crane took hold of it and

plunged it vertically into the bath; this should be done very quickly to prevent deformation of shaft.

The tempering tank is circular, about 6.5 feet in diameter and about 20 feet deep, and contains from 35 to 40 tons of water. Fresh water is admitted at the bottom of the tank by a system of pipes, and an overflow pipe carries off the excess. The bath may be heated by means of steam. The tank is let into the ground, leaving about 3 feet projecting above the surface.

The temperature of the bath for the first temper depends on the size of the piece tempered; for very large pieces, such as the shaft in question, it should be about 30° to 40° C., 86° to 104° F., and for small pieces, 80° or 90° C., 176° to 194° F. Moreover, the temperature of the bath depends on the nature of temper required, the cooler the bath the more pronounced the effect of the tempering. The shaft was left in the bath until perfectly cold.

(3.) *Reheating for Second Tempering.*—As the first temper leaves the metal brittle, the shaft, when cold, is reheated in the same furnace to a temperature of about 750° C., 1,382° F., judged by the eye as before, and corresponding to "dark red." This temperature is always the same, and is independent of the nature of the steel; this reheating takes about 9 hours; any small deformation is now corrected by a steam hammer.

(4.) *Cooling in the Air.*—When the shaft had reached the above desired temperature, it was withdrawn and allowed to cool in the air till a wooden batten, rubbed over the surface of the shaft, ceased to burn; the latter temperature being about 350° C., 662° F.

(5.) *The Second Tempering.*—When the shaft had reached this temperature, it was plunged a second time into the bath at 30° C., 86° F., and allowed to cool completely. The temperature of the bath for the second tempering is independent of the size of the piece or the nature of the steel.

This double tempering has the effect of (1) raising the elastic limit of the metal, (2) raising the breaking load, (3) slightly reducing the elongation.

The French claim that, by this process, they make a great

saving in the weight of their engines, at the same time retaining the relative strength, from the point of view of the resistance of the materials. Taking, for example, a connecting rod of the *St. Louis* (one engine, 4,767 I.H.P.), and of the *Brooklyn* (4,550 I.H.P.), the weight of the first is 1,232, and of the latter, 3,153 pounds,—a considerable difference.

Tests made at Indret in 1893, to determine the relative value of oil and water for tempering steel, showed that warm water gave as good results as oil, and now oil is used only for special objects such as springs. The results of these tests are given in the following table, where

N = natural state of metal.
TTW = double tempering in water.
TTO = double tempering in oil.

Where metal came from.	State.	Elastic limit. lbs. pr. sq. in.	Breaking load. lbs. pr. sq. in.	Elongation, %. To plastic limit.*	Elongation, %. Total.†
Steel for hexagonal bars (semi-hard).	N	41,250	87,450	9	23.5
	TTO	45,787	89,787	8.5	23
	TTW	47,575	96,387	6	23.5
do. furnished by Basse-Indre.	N	41,250	68,750	12.5	60
	TTO	55,000	85,075	8.5	45
	TTW 60°	57,750	89,787	7.5	36.5
	TTW 90°	53,075	76,037	12.5	58
do.	N	49,500	75,075	7.5	12
	TTO	55,000	82,500	8	16
	TTW 70°	64,075	90,750	7.25	11
Forged steel furnished by St. Chamond.	N	55,000	90,750	6.5	20.5
	TTO	89,787	106,700	8	53.5
	TTW 70°	91,575	110,825	7.5	53.5
Steel for hexagonal bar furnished by Firminy.	N	50,325	101,475	6.25	11.5
	TTO	73,287	115,225	6.75	17
	TTW 70°	73,287	113,575	7.25	27.5
Eccentric chariots, cast steel, of *Carnot*.	N	36,575	71,500	9.5	17
	TTO	58,575	88,000	6.25	9
	TTW (Warm)	59,537	92,537	4.50	10

* This column gives the elongation up to the point where "necking" begins, or, when the maximum load is reached. Prof. Unwin suggested for this point the term "plastic limit."

† This column gives the total elongation up to the breaking of the test piece.

CALIBRATION OF A WORTHINGTON WATER METER.

In a paper read before the American Society of Mechanical Engineers, Mr. John A. Laird gave the results of an extended series of meter calibrations made by himself.

The meter tested was a Worthington made entirely of brass, for hot water, and bought for testing purposes. It was used to measure the feed water during the two thirty-day duty tests on the Allis engines at the Chain of Rocks pumping station, St. Louis.

Daily tests of the meter were made, usually long enough to pass on an average of 300 cubic feet of water through the meter, with occasional tests extending over 12 and 24 hours. To check the meter, a carefully arranged system of piping and two tanks on scales were fitted.

The formula used to compute the correction is $\frac{W}{w\,M} = C$ where

W = total water weighed in pounds.

w = weight of one cubic foot of water at observed temperature.

M = cubic feet registered on meter.

When, upon finishing a daily test, considerable variation was shown between the computed correction and that of the previous day, a check test was run very carefully, and if the two came reasonably close together, the first was taken as the correction. If they did not agree, the last one was taken. It was noticed that in every instance the twelve and twenty-four hour tests checked within one-half of one per cent. of an adjacent daily test.

The water was all passed through filters before going to the meter, and air was let out of the meter body at least every eight hours. The meter was taken apart and examined before the beginning of the first test, between the two tests, and after the second test, and was found to be in good condition each time.

The corrections to the meter were plotted, and, with four exceptions, did not vary more than one per cent. from one day to another. Without going into the discussion of the probability of error, it seemed to the writer that, by careful calibration, results could be obtained with the Worthington meter which would not be more than one-half of one per cent. in error.

SHIPS.

UNITED STATES.

Marietta and Wheeling.—These two twin screw gunboats, mentioned on page 401 of the May number, have completed their official trials. As the trials and the vessels will be described in full in the November JOURNAL, only the principal results of the trials are given here. Both vessels were tried by the "standardized revolutions" method.

The *Marietta* was tried on May 25 and 26, the mean speed for four hours being 13.02 knots; revolutions per minute, 231.8; I.H.P., 1,054.08.

The *Wheeling* was tried on May 28 and 29, the mean speed being 12.88 knots; revolutions, 231.4; I.H.P., 1,079.78.

Princeton.—The last of the gunboats, named on page 799 of Volume VIII, was successfully launched on June 3 by Messrs. J. H. Dialogue & Son, Camden, N. J.

Dupont.—This torpedo boat, mentioned on page 401 of the May number, started on her official trial on July 15. This trial was interrupted by foul condensers. Another trial was started on July 16. After running well for a short time at about 405 revolutions per minute, the starboard engine was stopped on account of a bent piston rod of the 2d L.P. cylinder. Soon after, the piston valve of that cylinder stuck and wrecked the valve gear. The boat returned to the contractors' works using the port engine.

Torpedo Boats Nos. 19, 20 and 21.—Bids for the construction of these boats, the chief characteristics of which were given on page 402 of the May number, were opened at the Navy Department on June 21. The bids, with one exception, are given in the table. The exception was an informal bid by Mr. R. B. Painton for one or two boats, of 350 tons and 5,000 I.H.P., the price for one boat being $250,000, and for two boats, $225,000 each.

	Harlan & Hollingsworth Co.			Union Iron Works.	
	A.	B.	C.	A.	B.
Price for one boat, dollars	236,000*	215,000*	213,000*	245,250	225,000
Price for two boats, each, dollars	233,500	212,500	210,500	No bid.	220,000
Length over all, feet and inches	231–4	220–8	213–8	228–0	213–6
Length on trial water line, feet and inches	225–0	212–6	205–6	228–0	213–6
Beam, extreme, feet and inches	22–0	21–4	21–4	20–4	19–2
Beam, on trial, water line, feet and inches	21–3	20–8	20–8	20–0	19–0
Depth at side, feet and inches	15–0	14–9	14–9	13–6	12–10
Depth at center, feet and inches	15–8	15–9	15–9	14–4	13–10
Freeboard, amidship, feet and inches	8–6	8–9	8–9	7–3	6–10
Freeboard at stem, feet and inches	11–0	11–0	11–0	11–0	10–6
Draught, trial, feet and inches	6–6	6–0	6–0	5–7	5–5.5
Draught to clear screws, feet and inches	7–3	6–7	6–7	8–0	7–0
Displacement, trial, tons	340	276	267	268	238
Displacement, load, tons	?	?	?	330	284
Cylinder diameters, inches	21.5 32.5 34 (2)	20.5 31 32 (2)	20.5 31 32 (2)	20.5 30 31 (2)	20 29 30 (2)
Stroke, inches	18	18	18	20	18
Revolutions per minute	400	400	400	400	400
Grate surface, square feet	271.4	225	239	?	?
Heating surface, square feet	?	?	?	?	?
Working pressure	240	240	240	240	240
I.H.P.	7,200	6,500	6,500	6,400	5,600
Bunker capacity, tons	?	?	?	90	70†
Coal carried on trial, tons	?	?	?	22	20
Total weight carried on trial, tons	60	50	50	48.5	41.6
Armament — Torpedo Tubes	2	2	2	2	2
Armament — 6-pdr. R. F. guns	7	6	6	6	4
Boilers	4 Thorny.	3 Thorny.	4 Thorny.	4 Thorny.	3 Thorny.

* For types A and B, $449,000; for types A and C, $447,000.
† Coal at load displacement, 50 tons.

Columbian Iron Works.		J. H. Dialogue & Son.		Geo. Lawley & Son.	Wm. Cramp & Sons' S. and E. B. Co.	Bath Iron Works.	Chas. Hillman S. and E. B. Co.	Gas Engine & Power Co.	Wolff & Zwicker Iron Works.
A and B.	B and D.	A.	B.						
A, 210,000 B, 195,000	225,000	269,000	243,000	280,000	245,000	217,900	230,000	210,000	214,500
A, 207,500 B, 192,500	219,000	No bid.	239,000	No bid.	No bid.	216,000	No bid.	205,000	212,000
209–7	209–7	225–0	215–0	233–0	220–0	176–5	217–8	206–9	197–0
208–3	208–3	223–4	213–4	230–0	220–0	176–0	216–10	205–0	191–8
20–2	20–2	21–0	20–0	22–10	20–6	19–0	20–7	19–0	20–5
19–4	19–4	?	20–0	22–10	20–6	18–0	20–7	18–3	20–2
13–0	13–0	13–6	13–0	14–9	12–0	11–1	13–6	13–5	11–6
14–4	14–4	?	14–3	15–4	13–0	12–0	14–3	14–1	12–9
7–0	7–0	?	7–0	8–10	?	5–8	7–6	7–5	6–6
9–9	9–9	?	7–6	17–2 to forecastle	?	6–0	9–6	10–0	8–8
6–0	6–0‡	?	6–0	5–11	?	5–6	6–0	6–0	5–0
7–6	7–6	?	8–0	8–9	?	10–0	7–8	8–0	8–6
230	260‡	270	243	340	302	242	270	235	247.5
?	?	?	?	410	?	300	?	265	360
?	?	20.5 32 32 (2)	20.5 30 30 (2)	22 31.5 33 (2)	H.P. to be not less than 20.5	19.5 28 42	20.25 30 30 (2)	20 29 30 (2)	19.5 31.75 35 (2)
?	?	18	18	18	18	24	18	18	18
?	?	?	?	400	?	?	400	400	?
?	?	216	196.5	?	?	156	?	?	280
?	?	13,600	12,060	?	12,000	7,296	?	?	15,400
?	?	215	210	?	250	230	240	245	250
5,600	6,000	6,300	5,600	7,000	?	6,000	5,800	5,600	?
?	?	?	96.5	120	80	70	70	?	131
A, 17 B, 15.3	C, 19 D, 17	22	20	30	22	?	22	20	20
A, 35 B, 28.5	C, 42 D, 32	48.5	41.6	60	48.5	41.6	48.5	41.5	41.6
2	2	2	2	2	2	2	2	2	2
4	4	6	4	7§	6	4	4	4	4
?	?	?	3 Thorny.	4 Thorny.	?	?	3 Thorny.	Seabury.	?

‡ If displacement and other dimensions are correct, the draught must be wrong. If draught is correct, displacement must be wrong.

§ And two 1-pounders.

Contracts were awarded in July to the Harlan & Hollingsworth Co. for one boat on their bid A, and to the Gas Engine & Power Co. and the Wolff & Zwicker Iron Works, one boat each.

Atlanta.—Extensive alterations are to be made in the machinery of this partially-protected cruiser of 3,189 tons' displacement.

The principal data of this cruiser were given in Volume I of the JOURNAL. When completed, these changes, which are to be made at the New York Navy Yard, will bring the vessel more nearly up to date. The more important changes are as follows:

Boilers.—The eight single-ended cylindrical boilers will be removed and six new boilers put in their place. Four of the new boilers will be of the Babcock and Wilcox water tube type, and the remaining two, cylindrical, single-ended, all designed for a working pressure of 180 pounds per square inch. The fire rooms will be fore-and-aft, as before, but space will be gained for a new athwartship bunker of about 102 tons' capacity.

Engines.—The old three-cylinder compound engine, with the H.P. cylinder between the two L.P. cylinders, will be converted into a triple expansion engine. The old forward L.P. cylinder, 74 inches in diameter, will be replaced by a new H.P. cylinder 34 inches in diameter. The old H.P. cylinder, 54 inches in diameter, will be bushed to make its diameter 50.5 inches and to serve as the I.P. cylinder of the new engine. The other L.P. cylinder will be retained for the same purpose in the new engine. The forward condenser will be removed, and the internal arrangement of the after one will be changed to give a better distribution of the steam and more cooling surface. The independent engines for driving the old air and circulating pumps, and the forward air and circulating pump will be discarded. The after air pump will be worked from the L.P. engine, and the circulating pump will be blocked off. A new centrifugal circulating pump will be installed.

The following table shows the main features of the old and new machinery.

	Old machinery.	*New machinery.*
I.H.P.	3,850	3,500 est.
Weight, tons	662 4	539 08
Grate surface, square feet	400	303
Heating surface, square feet	10,146	10,824
Coal carried, tons	490	592
Cylinders and stroke, inches	54, 2 of 74 × 42	34, 50.5, 74 × 42
Revolutions per minute	72.2	90 est.
Steam pressure	90	180

T. A. M. Craven.—The name of this torpedo boat, given on page 401 of May number as *T. A. Craven*, has been changed as above.

Foote.—This torpedo boat, named on page 401 of the May number, has made her official trial. A detailed description of this boat and her class will be published in the November JOURNAL.

AUSTRIA.

As the result of exhaustive experiments, the Austrian Government has determined to fit the Yarrow boiler in the cruiser building at Pola, of 8,000 horse power. There will be eight boilers in all, having 2,500 feet of heating surface each. These boilers, as well as the machinery for the vessel, will be constructed by the Stabilimento Tecnico, Trieste.

A contract has also been made with Messrs. Yarrow & Co. for four first class torpedo boats of the improved *Viper* type.

BRAZIL.

Barrozo.—This steel sheathed cruiser, built by Sir W. G. Armstrong, Whitworth & Co., Elswick, and described on page 806 of Volume VIII, completed her trials on April 30.

On the six hours' trial under natural draft, a mean speed of 19.5 knots was attained, and on the four hours' forced draft trial, 20.5 knots. On each trial, the contract speed was exceeded by one-half knot.

CHILI.

O'Higgins.—This steel sheathed cruiser, described on page 143 of the February number, was successfully launched on May 17 by Sir W. G. Armstrong, Whitworth & Co., Elswick.

The draught of the vessel will be 22 feet.

The barbettes for the 8-inch guns and the casemates are 6 inches, the conning tower, 9 inches, and the protective deck, from 1½ to 2 inches thick.

The expected speed is now given as 21.25 knots. The coal supply will be about 1,200 tons.

ENGLAND.

———.—This new battleship, which is the only one to be built by contract under this year's programme, is to be laid down by the Naval Construction Company of Messrs. Vickers, Sons & Co., Barrow-in-Furness. The vessel will be almost identical with the *Canopus* class, and is designed to go through the Suez canal.

The length will be 390 feet; beam, 74 feet; depth, 43 feet; draught, 26 feet; and displacement, 12,950 tons.

The engines, boiler, armor and armament are the same as for the *Canopus* class, described on page 807 of Volume VIII.

Andromeda.—This first class sheathed cruiser, described on page 813 of Volume VII, was successfully launched on April 30. This vessel was laid down at the Pembroke Dockyard on December 2, 1895.

The launching weight, including the cradles, was 5,900 tons, the draught, after taking the water, being 12 feet 2 inches forward, and 19.5 feet aft. The camber of the ways was 9 inches in 300 feet. About 350 tons of the machinery were in place at the time of launching.

The total weight of the finished hull will be 6,975 tons, and the displacement of the finished vessel, at the mean load draught of 25.25 feet, 11,000 tons.

The twin screw engines are designed to develop 16,500 I.H.P. with 110 revolutions per minute and a steam pressure of 250 pounds per square inch at the engines. The resultant speed, on an 8 hours' trial at sea, is to be 20.5 knots. The propellers are of bronze and three-bladed. The diameter is 17, and the pitch, 22.5 feet.

The total estimated cost of the finished vessel is given in this year's Navy estimates as $2,738,610, of which $708,940 will be

for the propelling machinery, $18,725 for auxiliary machinery, and $155,500 for guns. The machinery is building by Messrs. Hawthorn, Leslie & Co., Newcastle-on-Tyne.

Arrogant.—This second class cruiser, described on page 617 of Volume VIII, made an eight hours' full power trial on June 22, but no data are published.

This vessel is the first Government-built cruiser fitted with Belleville boilers. Elaborate tests of one of the boilers for this vessel were made at the Government factory at Keyham, under various pressures up to 250 pounds per square inch.

The masts of this vessel have been reduced from the designed 160 feet to 140 feet.

Pyramus.—This third class cruiser of the *Pelorus* type, built by the Palmer's Shipbuilding Co., and described on page 391 of Volume VIII, was successfully launched on May 15.

Spanker.—The following particulars of the new DuTemple boilers and their trials, from "Engineering," London, are additional to those given on pages 392 and 835 of Volume VIII.

The four boilers were built by the Société Anonyme duTemple at Cherbourg, France. There are 900 tubes in each boiler, their outside diameter being $1\frac{3}{16}$ inches. The total weight of boilers and all fittings, including firebars, firebrick, funnels, feed pumps and water to working level, is 61 tons. (This is slightly different from the weight given by Mr. Malfatti.—EDIT.) The weight of one boiler and water, without fittings, except firebars, gauges and firebrick, is 14 tons 5 cwt. There is one feed pump to each pair of boilers, and the regulation of the water supply is by hand. The quantity of water evaporated per hour on trial was 4.3 pounds per square foot of heating surface, and the quantity of coal burned per square foot of grate per hour at the above rate of evaporation was 20.3 pounds. The quantity of water evaporated per square foot of heating surface per hour at full speed running was 11.07 pounds, the steam pressure in boilers being 214 pounds per square inch. The quantity of water evaporated per hour for each ton weight of boiler, with all fittings, funnels, feed pumps and water to working level, was 1,542 pounds.

Salamander.—This torpedo gunboat is undergoing a refit at

the Devonport Dockyard, the total expenditure for this refit being estimated at $157,405. The locomotive boilers are to be replaced by Thornycroft water tube boilers, the estimated cost of these being $59,375.

Earnest.—This destroyer, built by Messrs. Laird Bros., Birkenhead, has completed the official trials.

These vessels are 210 feet long; their beam is 21 feet 7 inches; mean load draught, 5.25 feet; and displacement, about 320 tons. The armament consists of one 12 and five 6-pounder rapid fire guns and two deck torpedo tubes. The complement consists of 58 officers and men. The coal capacity is 90 tons.

Two trials, made about the middle of May, were interrupted by leaky boiler tubes. A third trial, on May 17, was stopped by the breakdown of one of the main feed pumps. On May 19, the coal consumption trial was made under full power, the mean speed over the mile being 30.38, and for the three hours, 30.1 knots. The coal consumption was within the contract limit of 2.5 pounds per I.H.P.

On May 24, the full power speed trial was made, the mean speed on the mile being 30.19, and for the three hours, 30.12 knots. The runs are given in detail below with those of the *Griffon*.

Griffon.—Another Laird-built destroyer, and a sister vessel of the *Earnest*, has completed the official trials.

A trial was made previous to May 25, but, as a speed of only 29.5 knots was attained, it was not satisfactory, and new propeller blades were fitted. Then, on May 25, a satisfactory full power speed trial was completed, the mean speed on the mile being 30.04, and for the three hours, 30.02 knots. The runs in detail were as follows:

	Earnest.		*Griffon.*	
	M. S.	Knots.	M. S.	Knots.
1st mile	1·58½	30.38	1·59	30.26
2d do.	1·58½	30.38	2· 0½	29.88
3d do.	1·59	30.26	1·59	30.26
4th do.	2· 1	29.75	2. 0½	29.88
5th do.	1·58	30.51	1·59	30.26
6th do.	2· 0	30.00	2· 1	29.75

On June 1, another full speed trial was made, the mean speed for the mile runs being 30.2 knots with 370 revolutions per minute, and for the three hours, 30.15 knots.

Quail.—Messrs. Laird Bros., the builders of this torpedo boat destroyer, described on page 172 of the February number, have made a series of experiments to reduce the vibration of the engines.

Two balanced weights, of a combined weight of 540 pounds, were secured to the H.P. crank webs, and two others, weighing together 645 pounds, were secured to the L.P. crank webs. The engines were then run at various speeds up to full speed, the vibrations being recorded. It was found that the vibrations, both horizontal and vertical, were only one-half of those recorded before.

Wolf.—This 30-knot destroyer was successfully launched by Messrs. Laird Bros. on June 2.

Foam.—This 30-knot destroyer, built by Messrs. Thornycroft & Co., and described under the sister vessel *Desperate*, on page 182 of Volume VIII, has finished satisfactory trials. On April 30, a three hours' full power trial was made off Chatham dockyard in rough weather. The mean speed for three hours was 30.093 knots, and for the six runs over the measured mile, 30.127 knots.

Another three hours' full power trial was made on May 18. Steam pressure, 208 pounds per square inch; revolutions per minute, starboard, 394.6, port, 389.6; I.H.P., starboard, 2,786, port, 2,871, total, 5,657; speed, 30 knots.

Star.—The trials of and accident to this 30-knot destroyer were mentioned on page 418 of the May number. The following additional information is from "Engineering," London.

The air pressure on the trial of April 5 was 3.25 inches, and the steam pressure, 232 pounds per square inch.

The twin screw engines have cylinders 18, 27.5 and 42 inches in diameter, the stroke being 18 inches. The valves are all of the piston type. The main steam pipes have separators, and the automatic drain cocks were found in good working order after the accident. No doubt is now felt that the cause of the

mishap was the fracture of one of the crank pin bearing bolts. There had been a hidden flaw which was not discovered, in spite of the very complete and elaborate tests carried out in accordance with Admiralty requirements.

Chamois.—This destroyer, built by the Palmer's Shipbuilding Co., and of which some particulars were given on page 174 of the February number, made a satisfactory full speed preliminary trial on May 7. The load carried was slightly greater than the contract requirement. For the three hours, the mean speed was 30.336 knots, the revolutions per minute being 386.2.

The designed displacement of these destroyers is 300 tons, and the designed I.H.P. of the twin screw triple expansion engines, 5,900. The armament consists of four 6-pounder rapid fire guns and two deck torpedo tubes. Four Reed water tube boilers are installed.

Whiting.—Another of the Palmer-built destroyers, and a sister vessel of the *Chamois*, has completed her official trials. Preliminary trial results were given on page 420 of the May number.

The first trial was made on May 10. Revolutions for three hours, 392.7; I.H.P., 6,231; coal per I.H.P., 2.5 pounds, approximately; speed, 30.167. During the latter part of the trial, when the displacement was somewhat less than at the start, a run with the tide was made over the mile at the rate of 32.84 knots.

On May 14, the second trial was made, the I.H.P. and coal consumption being slightly less than on the first trial, although there was no coal allowance. For the three hours, the mean speed was 30.21 knots, the revolutions per minute being 397.95, and for the six runs over the mile, 30.42 knots. There was no perceptible vibration of the engines or the vessel. The sea was calm, but there was a 2-knot tide.

Flirt.—This 30-knot destroyer was successfully launched on May 15 by the Palmer's Shipbuilding Co.

Fairy and **Osprey.**—These 30-knot destroyers, built by the Fairfield Co., Govan, were successfully launched on May 29 and April 17, respectively.

Sylvia and **Violet.**—These 30-knot destroyers, built by Messrs.

Doxford & Sons, Sunderland, were successfully launched on July 3 and May 3, respectively.

The length is 227.5 feet; beam, 22 feet; draught 9 feet; displacement, 300 tons; and the designed I.H.P., 6,000.

The armament will consist of one 12 and five 6-pounder rapid fire guns and two torpedo tubes. The complement will be 58 officers and men, and the coal capacity, 80 tons.

FRANCE.

Hoche.—This battleship, finished in 1891, and described in Volume III, will receive new Belleville boilers in place of the cylindrical boilers now in the vessel. The following data of the old and new boilers are from "LeYacht," Paris.

There are, at present, eight straight-through boilers of the Admiralty type, each boiler having three furnaces, the working pressure being 85.5 pounds per square inch. (The engines, of the vertical twin screw type, with cylinders 62 and 79⅛ inches in diameter, and a stroke of 39.4 inches, were designed to develop 11,836 I.H.P.—EDIT.) The total grate surface is about 560 square feet. They were designed to burn about 50 pounds of coal per square foot of grate surface under forced draft. On the official trial, the I.H.P. attained was not quite 10,850, the coal consumption being 47.5 pounds per square foot of grate surface, and the speed, 15.9 knots.

The new boilers will be of the 1896 Belleville type, with economizers. There will be sixteen of these, arranged in four groups, the total grate surface being 866.5 square feeet, and the working pressure being about 70 pounds above that at the engines, or about 155 pounds per square inch. There will be one smoke pipe, as at present. With the new boiler power, the designed I.H.P., 11,836, will be easily attained and the speed increased slightly. On account of the unfavorable lines of the fore body, no greater speed than 16 knots can be expected, no matter how great the increase in power.

Charles Martel.—This battleship has finished her official trials. Preliminary trials were described on page 847 of Volume VIII. On the six hours' full power trial on May 5, a mean

speed of 18.13 knots was obtained on the course off the Hyères Islands. The I.H.P. was 14,791, and the coal per I.H.P. per hour, 1.78 pounds.

On the coal consumption trial of 24 hours' duration, the I.H.P. was about 11,830. The coal per I.H.P. per hour was less than the contract limit, the contractors receiving a premium of about $4,200 on this account.

Massena.—This triple screw battleship, described on page 423 of the May number, made her first preliminary trial in free route in the third week in June. All boilers were used. A speed of only 16.8 knots was obtained, the number of revolutions per minute being greater than 120.

D'Entrecasteux.—The following particulars of this protected cruiser are from "Le Yacht," Paris, and are additional to those given on page 626 of Volume VIII.

The protective deck is 3.94 inches thick on the inclined sides. Above this deck is a horizontal deck, .79 inch thick. The cellular spaces between these are used for coal bunkers and store rooms.

The two 9.45-inch guns are in closed turrets. There are besides, twelve 5.45-inch rapid fire guns, eight in armored casemates, and four above these on deck, all with 2.13-inch shields; twelve 1.85-inch and several 1.46-inch rapid fire guns; and six torpedo tubes, two of which are under water. Electricity is used for working the guns.

The twin screw engines are of the triple expansion type. The I.H.P. under forced draft, and burning 26.6 pounds of coal per square foot of grate surface, is to be 13,315, and the resultant speed of vessel, 19 knots.

There are five cylindrical, return tube boilers, four of these are forward of the engines, and the other one, aft between the shafts of the engines. The working pressure will be 142 pounds per square inch.

The normal coal capacity will be 640 tons, but 985 tons may be carried.

The weight of the hull will be 2,942 tons, armor, 1,644 tons, armament, 474.4 tons, and machinery, 1,373 tons.

The total estimated cost is $3,349,000.

Amiral Pothuau.—Additional results of the trial, made on February 26, and mentioned on page 424 of the May number, are as follows. They are from "Le Yacht," Paris.

The I.H.P. was 6,751; coal per I.H.P. per hour, 1.77 pounds; and the exact speed, 17.787 knots.

Fleurus.—Referring to page 425 of the May number, it is now reported that the Trial Board has definitely rejected the Admiralty boilers. The vessel has been placed out of commission, and water tube boilers will be put in.

D'Assas.—This second class cruiser, mentioned on page 425 of the May number, has, according to "Le Yacht," Paris, finished her preliminary contractors' trials, and in June, made the first of her official trials. This trial was made with all of the twenty boilers, the engines to develop about 5,900 I.H.P., and was fairly satisfactory.

Among the official trials to be made, there is one at full power, forced draft, and of four hours' duration. If the I.H.P. developed is less than 9,173, a penalty of $40 per I.H.P. will be imposed. This power must be obtained with a coal consumption not greater than 32.77 pounds per square foot of grate surface, the penalty for every pound above this amount being about $36.

It is reported that this vessel exceeds her contract draught of water, and that her stability is not absolutely assured under certain conditions. The Trial Board has recommended that these defects be remedied at the expense of the contractors.

Lavoisier.—This third class cruiser, similar to the *Galilée*, was successfully launched at Rochefort on April 17. The following particulars are from "Le Yacht," Paris.

The order to build this cruiser was given on December 29, 1893, but the keel was not laid until January 7, 1895.

The length of the cruiser, as finished, is 330.24 feet; beam, 35.11 feet; draught, aft, 17.88 feet; displacement, 2,280.4 tons. The hull is of steel, not sheathed, and there are two smoke pipes and two pole masts.

The armament will consist of four 5.45-inch rapid fire guns, placed amidship in broadside and protected by 2.13-inch chrome steel shields; two 3.94-inch rapid fire guns, similarly protected,

one in the bow, and the other in the stern; eight 1.85-inch and six 1.46-inch rapid fire guns; and two torpedo tubes above water.

The twin screw engines are of the vertical triple expansion type, designed to develop 6,312 I.H.P. and give the vessel a speed of 20 knots. With natural draft, the speed is to be about 18.5 knots. The boilers are of the Belleville type, which will be fitted to burn coal and liquid fuel.

The bunker capacity is 222 tons of coal. The complement will consist of 11 officers and 237 men.

The total cost of the vessel is about $1,010,120.

Durandal and **Hallebarde.**—These vessels, variously called torpedo boats and torpedo gunboats, were mentioned on page 850 of Volume VIII. Both are building by Mr. Normand at Havre.

The length is 180.48 feet; beam, 19.48 feet; draught, aft, 10.49 feet; displacement, 295.26 tons; speed, 26 knots. They will have twin screw triple expansion engines of about 4,730 I.H.P., and a steaming radius of 2,500 miles at 10 knots.

Espingole and **Fauconneau.**—These torpedo boat destroyers, according to "Le Yacht," Paris, are building by Mr. Normand at Havre, having been ordered in April. This type was mentioned on page 178 of the February number by the building letter M_2. These boats will be slightly larger than the *Durandal*, although having the same armament. They are to be finished in two years.

The length is 183.7 feet; beam, 20.67 feet; draught, aft, 9.84 feet; displacement, 306 tons; speed, 26 knots.

The armament will consist of one 2.56-inch rapid fire gun on the conning tower forward; six 1.85-inch rapid fire guns; and two deck torpedo tubes, one amidship and the other aft.

The twin screw, vertical, triple expansion engines are to develop 4,734 I.H.P. under forced draft, giving the vessel a speed of 26 knots. For a speed of 14 knots, the I.H.P. will be 789.

There will be two Normand-Sigaudy boilers.

GERMANY.

Freya.—This steel, triple screw, second class cruiser, a sister vessel of the *Victoria Luise*, which was described on page 425 of

the May number, was successfully launched at the dockyard, Danzig, on May 4. While building, the vessel was known as Ersatz *Freya*. This vessel will have twelve Niclausse boilers.

The engines and boilers are building by the Oder Shipbuilding and Engineering Co., Grabow.

HOLLAND.

Zeeland.—This protected cruiser, described on page 829 of Volume VII, was successfully launched by the Schelde Co., Flushing, on March 20.

Gelderland, Noord-Brabant and **Utrecht.**—These three protected cruisers, of the *Zeeland* type, are building at Feijenoord, Flushing and Amsterdam, respectively, according to the "Mittheilungen aus dem Gebiete des Seewesens," Pola.

The points of difference between these cruisers and those of the *Zeeland* type were given in the shipbuilding programme on page 131 of the February number.

ITALY.

Ammiraglio Saint Bon.—This battleship, described on page 196 of Volume VIII, was successfully launched at Venice on April 29.

The twin screw, three cylinder, triple expansion engines are designed to develop 13,315 I.H.P. when running at 112 revolutions per minute, and to give the vessel a speed of 18 knots.

Agordat and **Coatit.**—These two protected torpedo cruisers of 1,292 tons' displacement were partially described on page 199 of Volume VIII. From a paper by Mr. G. Malfatti, Engineer, Italian Navy, published in the "Rivista Marittima," Rome, the following data and description of the Blechynden boilers are taken.

The *Agordat* is to develop 7,397, and the *Coatit*, 7,890 I.H.P. The boilers of the *Agordat* are arranged in pairs with their backs to the central line, with one smoke pipe for each group of four boilers. The four boilers of the *Coatit* are similarly arranged, with one smoke pipe for two boilers.

	Agordat.	*Coatit.*
Number of boilers	8	4
Heating surface, total, square feet	20,498	19,188
Grate surface, total, square feet	344 5	360
H.S. ÷ G.S.	59.5	53.3
Floor space occupied by boilers, square feet	936.5	812.7
boiler compartments, square feet	1,534	1,534
Height of boilers, feet, about	8.25	9.5
compartments, feet, about	9.84	9.84
Weight, total, without water, tons	138.13	120.08
with water, tons	169.14	138.78
per I.H.P., pounds	51.2	39.4

The above weight includes the boilers proper, the smoke pipes, all accessories and auxiliaries in the boiler compartments, the steam and water piping, and the floor plates.

———.—This torpedo boat destroyer is building by Messrs. N. Odero & Co., Sestri Ponente, Italy. The displacement is about 260 tons and the I.H.P., 4,734. Mr. G. Malfatti, Engineer, Italian Navy, gives the following data of the Blechynden boilers in a paper published in the "Rivista Marittima," Rome.

The four boilers are arranged in three compartments, with a smoke pipe for each compartment. There is one boiler in each of the end compartments and two boilers, placed back to back, in the middle compartment. The total grate surface is 208.8, and the heating surface, 985.5 square feet, the ratio of heating to grate surface being 47.2.

The total weight of the boilers, smoke pipes, all accessories and auxiliaries in the boiler compartments, steam and water piping, and floor plates, without water, is 51.57 tons, and with water, 61.81 tons. The total weight with water, per designed I.H.P., is 29.2 pounds.

JAPAN.

Shikishima.—This is the name of the battleship building by the Thames Iron Works and described on page 430 of the May number.

———.—This first class battleship is building by the Clydebank Engineering and Shipbuilding Co., and will be similar to H.M.S. *Jupiter*, built by this firm and described on page 406 of the May number.

The contract includes the supplying and fitting of nickel steel armor plates.

Chitose and **Kasagi.**—These are the names of the cruisers building by the Wm. Cramp & Sons' Co. and the Union Iron Works, respectively, and described on page 182 of the February number.

Takasago.—This cruiser, built by Sir W. G. Armstrong, Whitworth & Co., was successfully launched at their Walker yard on May 18. She was built on the *Yoshino's* lines. The following data are from the "London Times" and other sources.

Length, 360 feet; beam, 46.5 feet; draught, 17 feet; displacement, about 4,160. The expected speed is 22 to 24 knots. The protective deck varies from 1.75 to 4.5 inches in thickness. The conning tower is 3 inches thick.

The armament will consist of two 8-inch, ten 4.7-inch, twelve 12-pounder and six 2.5-pounder rapid fire guns, and five torpedo tubes.

PORTUGAL.

Rainha de Amelia.—This cruiser, building at Lisbon from designs by Mr. A. Croneau, is similar to, though slightly smaller than the two cruisers building in France, and described on page 183 of the February number.

The length is 246 feet; beam, 36 feet; depth, 21 feet; draught, aft, 14.75, mean, 13.5 feet; displacement, 1,634 tons.

The twin screw, vertical, triple expansion engines are to develop 2,959 I.H.P. under natural draft, and 4,438 I.H.P. under forced draft, giving the vessel a speed of 16 and 17.5 knots, respectively.

The armament will consist of four 5.9-inch, four 3.94-inch and two 1.85-inch rapid fire guns; four machine guns; and two 14-inch torpedo tubes.

The complement will be about 250 officers and men.

RUSSIA.

Abrek.—This twin screw torpedo gunboat, of the Black Sea Fleet, was built by Messrs. Creighton at Abo, Finland. The following data are from the "Marine Rundschau," Berlin, from Russian sources.

The length on water line is 212.2 feet; beam, 24.93 feet; mean draught, 8.53 feet; displacement, about 526 tons. The hull plates are of steel from .24 to .35 inch thick, the plates under water being galvanized, and the longitudinal seams, double-riveted. There are nine main water tight bulkheads reaching to the upper deck. Tracks are laid on the upper deck for the handling and moving of torpedoes. There are two torpedo tubes, one in the bow, and one on deck. The furniture and other equipment in the quarters are of galvanized steel.

The twin screw triple expansion engines are to give the vessel a speed of 21 knots when running at 300 revolutions per minute. The bed plate is of cast iron. The air pumps are worked from the L.P. crossheads. Stephenson's link gear is used. The engines are arranged to work jet-condensing, and each is fitted with an automatic stop, in case of an accident to a shaft or propeller. The propellers are of bronze.

A Rayner distilling apparatus, capable of supplying 10 tons of fresh water per 24 hours, is installed.

There are four Normand boilers, with a working pressure of 200 pounds per square inch. One I.H.P. is to be developed for every 3.04 square feet of grate surface, and 27.6 I.H.P., per square foot of heating surface, the latter being guaranteed by the builders.

There are thirteen bilge ejectors and three Stone pumps, one of the latter being portable. There is one dynamo.

The vessel carries one steam cutter and three other boats.

The cost of the vessel, including armament, is about $261,000.

SPAIN.

Cristobal Colon.—This armored cruiser, built by Messrs. Ansaldo & Co., at Sestri Ponente, Italy, and described on page 854 of Volume VIII, has completed her official trials. The principal data of the finished vessel, and additional particulars of the Niclausse boilers from "LeYacht," Paris, are as follows. The trial data are from the "Rivista Marittima," Rome.

The length between perpendiculars is 328.1 feet; beam, 60.7 feet; draught, aft, 23.29 feet; displacement at load draught, 6,889

tons. There is a 6-inch harveyized nickel steel armor belt, and a central citadel with the same kind of armor, varying from 4.7 to 6 inches in thickness. The curved protective deck varies in thickness from .98 to 1.18 inches. Bilge keels are fitted. The vessel was built in sixteen months.

The armament consists of two 10-inch guns in barbette turrets, protected by 4.7-inch steel armor, ten 6-inch, six 4.7-inch, ten 2.24-inch and ten 1.46-inch rapid fire guns, two smaller guns and five above-water torpedo tubes. There is one military mast with two tops between the two smoke pipes.

The twin screw engines, built by Messrs. Ansaldo & Co., are of the vertical, inverted, triple expansion type, with cylinders 42, 63 and 93 inches in diameter, the stroke being 47 inches. The H.P. cylinders have piston valves, and the I.P. and L.P., double-ported slide valves, all being worked by double eccentrics and Stephenson's link motion. The cooling surface of the two main condensers is 14,640 square feet. The main engines were designed to develop 13,315 I.H.P. under forced draft and give the vessel a speed of of 19.5 knots. The I.H.P. of the auxiliary machinery is about 493, making the total I.H.P. 13,808. The propellers are four-bladed.

The twenty-four Niclausse boilers, which were built in Paris in three months, are connected in pairs having a common steam drum. There are four boiler compartments, two forward and two abaft the engines, each compartment, 17.38 feet wide and 43.31 feet long, containing three pairs of boilers. The fire room is outboard and 8 feet wide between the bunker and the boilers. Each pair of boilers is 14.07 feet wide, the depth being 8 feet, and the height over drum, 12.89 feet.

The total grate surface is 957.3, and the heating surface, 30,965 square feet; ratio of H.S. to G.S., 32.3 to 1. Each furnace has 288 grate bars. The water capacity of each pair of boilers is about 88.3, and the steam room, about 12.4 cubic feet. The steam pipes are of steel and are wound with steel wire.

The engineer inspector of the Bureau Veritas, who watched the construction of the boilers in Paris for the Messrs. Ansaldo & Co., gives, in "Le Yacht," the following weights which differ

considerably from those previously published on page 854 of Volume VIII.

Weight of the twenty-four boilers, without water, 275.59 tons; with water, 334.63 tons; total with water, all accessories and smoke pipes, 370.06 tons. Using the total weight, gives 26.8 pounds of boiler per square foot of H.S.; 865.9 pounds per square foot of G.S.; 60 pounds per I.H.P. (13,808 full power); and I.HP., full power, per ton of boiler, 3.73.

The trials were made with Italian firemen who had had only little training with this or any type of water tube boiler. The amount of coal for and time of firing each furnace were regulated with great care. The coal was patent fuel, made at Nœux in France, and was stowed in bags of 110 pounds each. It burned freely and was easily worked.

On April 10, a run was made with twelve boilers, to break in the firemen. With from 70 to 75 revolutions per minute, the I.H.P. developed was about 4,430. On the 13th, another trial was made with the other twelve boilers, the result being about the same.

On April 17, all boilers were used under natural draft. With the engines making from 96 to 97 revolutions per minute, the I.H.P. was 10,553, this power being developed easily. Similar results were obtained on another trial on April 21. These preliminary trials being satisfactory, the vessel was docked for the final acceptance trials.

In view of the favorable results already obtained, the Trial Board decided to make a trial at full power under natural draft, and, if the contract requirements were fulfilled, to omit the prescribed forced draft trial.

On April 27, the above trial was made and consisted of four runs over a measured mile and then a run in free route. For $3\frac{1}{2}$ hours the mean number of revolutions per minute was 96.2, and the mean I.H.P., 9,852. One set of indicator cards at 99 revolutions gave 10,584 I.H.P. The mean speed was 18.89 knots for the mile runs, and 19.35 knots from a run over a course of 24 nautical miles along the coast. Another trial, under similar conditions, was made on April 29, the mean speed being 19.29

knots, with about the same indicated power as on the first trial. The maximum power developed was, however, about 11,000.

The contract speed of 19.5 knots under forced draft having been attained very nearly with natural draft, the Trial Board waived the forced draft trial.

The remaining coal consumption trial, of six hours' duration, was made on May 4, under natural draft. The mean number of revolutions per minute was 92.1; I.H.P., 8,793; speed, 18.26 knots; coal per I.H.P. per hour, 1.64 pounds.

Carlos V.—This cruiser, built at Cadiz, and described on page 201 of Volume VIII, made a trial on March 22 with the following results, taken from the "Marine Rundschau," Berlin.

All twelve boilers were started and the vessel tried at the dock first, the steam pressure being 128 pounds per square inch. Later, she left for the free route trial, starting with 60 revolutions and making 11.75 knots. The engines were then worked up to 98 revolutions, the I.H.P. being about 14,795, and the speed, 19 knots. The sea was moderately heavy. Nixon's steam navigation coal was used. During the latter part of the trial, the wind and sea increased so much that the engines could make only 72 revolutions, giving a speed of about 16 knots. The trial was then stopped.

Reina Regente.—According to the "Revista General de Marina," Madrid, this first class cruiser is building at Ferrol, to take the place of the ill-fated cruiser of the same name which was lost in 1895. The new cruiser will have a displacement of 4,921 tons and a speed of 20 knots, the I.H.P. being 6,411.

Rio de la Plata.—This cruiser, according to the "Diario de Cadiz," is to be built by the Forges et Chantiers de la Mediterannée. The cost of the vessel will be defrayed by Spanish subjects on the Plate River.

The vessel will have a displacement of about 1,750 tons. The protective deck will be .39 inch thick on the flat, and .79 inch on the inclined sides. There will be two masts with military tops, and a large ram.

The armament will consist of two 5.9-inch, four 4.7-inch and

six 2.24-inch rapid fire Gonzales-Hontoria guns; two 1.46-inch Hotchkiss guns and several smaller guns; and two torpedo tubes.

The twin screw triple expansion engines are to develop about 7,100 I.H.P. under forced draft and give the vessel a speed of 21 knots. The speed with natural draft is to be 16.5 knots. Four Normand boilers will be installed. The coal capacity is to be 270 tons.

The vessel will carry two steam and six other boats.

SWEDEN.

Ejdern, Örn and **Tärnan.**—These single screw torpedo gunboats have a length of 223 feet; beam, about 27 feet; draught, 8.75 feet; displacement, about 665 tons; I.H.P., about 4,000; and speed, 19 knots.

The armament consists of two 4.7-inch and four 2.24-inch rapid fire guns and one torpedo tube.

MERCHANT STEAMERS.

Kaiser Wilhelm der Grosse.—This express steamer, built by the Vulcan Works at Stettin for the North German Lloyd Steamship Co., was successfully launched on May 4. This steamer was referred to on page 201 of the February number. The following additional particulars are from the "Nautische Rundschau," Vienna, and "Stahl und Eisen," Düsseldorf.

The length on deck is 649.6, and on the water line, 625 feet; beam, 66 feet; depth, 43 feet; load draught, 28 feet; load displacement, about 19,684 tons; gross registered tonnage, 13,800. The vessel was built as a four-deck steamer under the requirements of the German Lloyd, and those of the Admiralty for an auxiliary cruiser. There are sixteen athwartship bulkheads, reaching to the upper deck, and one fore-and-aft bulkhead in the engine room, dividing the vessel into eighteen main watertight compartments. The double bottom runs nearly the entire length of the vessel and is divided into twenty-two compartments. Bilge keels are fitted. The vessel will have accommodations for about 400 first class, 350 second class and 800 steerage passengers, and a complement of 450 officers and men. There will be two steel pole masts for schooner rig, four smoke pipes and twenty-four steel boats. The bunker capacity will be about 4,500 tons.

The twin screw engines are of the four-cylinder, four-crank, triple expansion type, balanced on Schlick's system, and are to develop between 27,000 and 30,000 I.H.P. The stroke of the engines is 68.9 inches. The total number of steam cylinders on board is 124.

There are twelve double-ended, eight-furnace boilers, and two single-ended, four-furnace boilers, arranged in four groups, with one smoke pipe for each group. Each pipe is 12.13 feet in diameter, and its top, 106 feet above the keel. The total number of

furnaces is 108. The propellers are of bronze, three-bladed, 22.31 feet in diameter, and have a pitch of 32.8 feet.

The launching weight was about 8,021 tons.

The following details of the crank shafts are from "Stahl und Eisen."

The crank shafts are built-up of Krupp's nickel steel, with a tensile strength of 88,580 pounds per square inch, and an elongation of 20 per cent. Each crank shaft is 45.81 feet long, and composed of four sections, each 11.45+ feet long. The crank shafts and pins are 23.62 inches in diameter, with a 9.45-inch axial hole. The crank pins are 26.38 inches long. The four sections of each shaft have the same dimensions, but the two end sections have balance weights on the cranks, these weights extending 52.4 inches from the center of the shaft. The cranks are 15.75 inches thick and have circular ends and sides, formed with a radius of 15.75 inches from the center of the crank pin. There are two coupling discs on each section, 40.9 inches in diameter and each 6.3 inches thick, and each fitted for 14 coupling bolts. The distance between the coupling disc and crank face of each section is 25.79 at one end, and 41.17 inches at the other.

The total weight of each crank shaft is 81.98 tons.

Kaiser Friedrich.—This express steamer, building by Mr. F. Schichau at the Danzig yard for the North German Lloyd, was described on pages 646 and 861 of Volume VIII. The following particulars of the crank shafts and the cylinder dimensions are from "Stahl und Eisen," Düsseldorf. The working drawing of the crank shaft, from which the dimensions given below were taken, shows that the diameter of the shaft and the throw of the crank, or the stroke of the engine, are greater than the figures given on pages 647 and 648 of Volume VIII. It is, therefore, probable that the cylinder diameters also were increased, and that the dimensions given below are correct.

The length of the vessel over all is 598.75 feet, and the gross registered tonnage, about 12,500.

The twin screw engines, of the five-cylinder, quadruple expansion type, working on three cranks set 120 degrees apart, have

cylinders 43.3, 64.2, 92.1 and (2) 93.3 inches in diameter, the stroke being 66.9 inches. Each engine is to develop about 12,000 I.H.P.

The crank shafts are of nickel steel, made by Mr. Fr. Krupp, Essen, with a tensile strength of 88,580 pounds per square inch and an elongation of 20.5 per cent. Each shaft consists of three sections, each forged in one piece. The two after sections are interchangeable, each 14.76 feet long; the forward section is 12.96 feet long. The total length of each crank shaft is 42.48 feet, its weight, 39.7 tons, and its outside diameter, 23.62 inches. The axial hole in the shaft is 9.45 inches in diameter, but is contracted, as it nears the crank and for a short distance in the crank, to a diameter of about 4.75 inches; from the contracted part to the inner face of the crank, the hole is again 9.45 inches in diameter. In the forward part of the forward section the hole is not contracted, but is 9.45 inches in diameter straight through. The distance between the coupling disc of each section and the face of the crank is 54.3 inches; the forward part of the forward section is only 37.4 inches long from the crank face to the end, and there is no coupling disc. The coupling discs are 43.3 inches in diameter and 5.51 inches thick. There are nine bolts and a straight-through key in each coupling.

The crank pins are 24.02 inches in diameter, 29.13 inches long, and have an axial hole, 9.45 inches in diameter. The cranks have straight sides and rounded ends, and are 29.13 inches wide and 14.96 inches thick.

The propellers are three-bladed, 20.34 feet in diameter.

Juniata.—This single screw steamer is building by the Harlan & Hollingsworth Co., Wilmington, Del., for the Merchants & Miners' Transportation Co.

The JOURNAL is indebted to the courtesy of Mr. T. Jackson Shaw, Superintending Engineer to the builders, for the following description.

Length over all, 293.5 feet, on water line, 271 feet 5 inches; beam, molded, 42 feet; depth of hold, 26 feet; draught, normal, 18 feet 8 inches; corresponding displacement 3,600, and carrying capacity, 1,230 tons.

The hull is of steel and has four decks. There are three main watertight bulkheads. There are accommodations for 104 first and 12 second class passengers. The fittings and furnishings of the staterooms, social hall and smoking room are very handsome and complete. There are three deck houses, containing the social hall, rooms for first class passengers, smoking room, toilet rooms, and quarters for the officers. The main saloon, finished in mahogany, is aft on the main deck and below the social hall, communicating with it by a grand stairway. Forward on this deck are the quarters for the crew, the galley and quarters for the second class passengers.

She will be schooner-rigged, having two pole masts. There is one smoke pipe.

The vertical, three-cylinder, triple expansion engine has cylinders 28, 45 and 72 inches in diameter, the stroke being 48 inches. The air, feed and bilge pumps are worked from the L.P. crosshead. The independent circulating pump is of the centrifugal type. The condenser is of cast iron and contains 4,625 square feet of cooling surface. The H.P. and I.P. cylinders have piston valves, and the L.P. cylinder, a slide valve, all worked by Stephenson link motion and reversed by direct steam gear.

There are four cylindrical steel boilers, each with three corrugated furnaces. The working pressure will be 160 pounds per square inch.

The boilers are each 13.5 feet in diameter and 11.5 feet long, the total grate surface being 274, and the heating surface, 7,780 square feet. There is one auxiliary boiler, 6 feet 10 inches in diameter and 9.25 feet long, having the same working pressure as the main boilers.

The propeller is of bronze with four blades, 16 feet in diameter, and has a pitch of 21.5 feet.

The engines were designed to develop about 2,800 I.H.P. and give the vessel a speed of 15 knots at normal draught.

Empire City.—This freight steamer, built by the Cleveland Shipbuilding Co., Cleveland, Ohio, for the Zenith Transit Co. of Duluth, Minn., was successfully launched on June 19. Some

particulars of this steamer were given on page 198 of the February number. The following additional particulars are from the "Marine Record," Cleveland.

The length over all is 426 feet, on keel, 406 feet; beam, 48 feet; depth, 28 feet; estimated carrying capacity, 5,000 gross tons on a mean draught of 16 feet. She is built on the channel bar system of open-hearth steel. The water bottom is five feet deep and is estimated to carry from 2,000 to 2,500 tons of water ballast. The main hold of the vessel is divided into four separate compartments by steel bulkheads. The deck house, of steel, is forward, and the crew space is aft and below the main or spar deck. This is a new departure. The cabins will be handsomely finished in quartered oak. The *Empire City* will have three pole spars.

A quadruple expansion engine, built by the same company, has cylinders 17, 26, 39 and 60 inches in diameter, the stroke being 40 inches. Two Babcock & Wilcox water tube boilers will be installed, the working pressure to be 250 pounds per square inch, reduced to 200 lbs. per square inch at the engines. All pumps are independent. Artificial ventilation is provided for the engine and fire rooms and the officers' quarters.

Williamson Bros.' steam steering gear, and the builders' steam deck winches are fitted.

There is a combined steam windlass and capstan, a steam capstan aft, and two amidship. The electric lighting plant consists of two separate sets of dynamos driven by vertical, direct-connected engines.

A speed of 12 knots is expected with the vessel loaded.

Oceanic.—This new steamer, building for the White Star Steamship Co., was mentioned on page 442 of the May number. The following particulars of the stern frame and brackets are from the "Engineer," London.

The steel stern frame is one casting, 53 feet high and 24.25 feet long over the keel piece. The sections of the posts are 21 by 11 inches. The weight of the rough casting was 41 tons, and, when finished, 35 tons. Attached to this frame will be the after propeller shaft brackets, each weighing 55 tons in the rough,

and 45 tons when finished. The height of the flanged portion of the bracket, that which is attached to the frame of the ship, is 26 feet, and its width, from center to center of the bosses, is 23 feet, the bosses being 4.25 feet in diameter and 5 feet 7 inches deep. The forward brackets, which are built entirely within the plating of the ship, will weigh 30 tons when machined.

These castings, which were made by the Darlington Forge Co., are said to be the largest ever made in Great Britain.

Andrew Carnegie.—This steel steamer, built by the Cleveland Shipbuilding Co. for the Wilson Transit Line, was successfully launched on February 20.

The length over all is 420, and on keel, 400 feet; beam, 48 feet; depth, 28 feet; estimated carrying capacity, 4,000 gross tons on a mean draught of 14.5 feet, and about 6,000 tons on 16.5 feet. The hull is built of open-hearth steel on the channel system. The double bottom is 5 feet deep and will hold about 2,000 tons of water ballast. She has three pole masts and one smoke pipe.

The engine is of the triple exansion type, with cylinders 23, 38 and 63 inches in diameter, the stroke being 40 inches. The propeller is 13 feet in diameter and has a pitch of 17 feet. There are three cylindrical boilers, each 12 feet in diameter and 12 feet long, the working pressure being 175 pounds per square inch. Williamson Bros.' steam steering gear and an electric lighting plant are fitted.

Niagara.—This steel sheathed steamer, described on page 443 of the May number, was successfully launched on May 29 by Messrs. F. W. Wheeler & Co. at West Bay City, Mich.

Kamakura Maru.—This steamer, described on page 205 of the February number, made her trials on the Clyde on May 7. Runs were made over the Skelmorlie mile and the trial continued for six hours. The average speed was 14.75 knots.

Socotra.—This steamer, built by the Palmer's Shipbuilding and Iron Company for the Peninsular and Oriental Steam Navigation Company, completed her trials on February 10.

The length between perpendiculars is 450 feet; beam, 52 feet; depth, molded, 33.5 feet. The vessel has three decks, two of

which are of steel, with poop, bridge and forecastle, and complies with the Admiralty requirements for transport service. There is a double bottom running the entire length of the vessel. The carrying capacity is about 6,000 tons dead weight on the summer freeboard. The engines are of the triple expansion type, with cylinders 22.5, 36.5 and 60 inches in diameter, the stroke being 48 inches. There are two cylindrical boilers fitted with Howden's forced draft.

During the trial the engines worked well at 83 revolutions per minute. A mean speed of 13.5 knots was attained on the measured mile.

Egypt.—This single screw steel steamer of the Peninsular and Oriental Co., and built by Messrs. Caird & Co., Greenock, Scotland, was launched on May 15. She is a sister vessel of the *India*, described on page 421 of Volume VIII.

The length is 500 feet; beam, 54 feet; depth, 37.5 feet; and registered tonnage, 8,000. The triple expansion, four cylinder engine is to develop 11,000 I.H.P. The shafting is of Vicker's steel, and the propeller blades of manganese bronze. Howden's system of forced draft is fitted. The cargo winches are all worked by hydraulic power. There will be accommodation for 500 saloon passengers.

Briton.—This steel twin screw steamer, built for the Union Steamship Co. by Messrs. Harland & Wolff, Belfast, was successfully launched on June 5, and is the ninth vessel built by Messrs. Harland and Wolff for this company.

The length is 530 feet; beam, 60 feet; gross tonnage, about 10,300. The general design of the smaller *Norman*, fully described on page 178 of Volume VII, has been followed. There will be accommodations for nearly 300 first class on the bridge, upper and middle decks, about 200 second class on the middle deck, and about 120 third class passengers in the poop, the last in large, airy rooms, containing eight berths each. There will also be open steerage accommodations for over 300. The first class saloon will be on the upper deck. The library, drawing room and the smoking room will be on the promenade deck. The entrance into the second class saloon will be provided with

sofas, &c., and will make a comfortable ladies' sitting room on deck. Large promenade decks will be a feature in the new steamer, as they are in the *Norman*. The officers will have well-ventilated rooms on the bridge deck. She is designed for carrying a large cargo or a considerable number of troops. Triple expansion engines will be fitted.

The following table of three steamers, of the same name, owned by this company will be interesting.

	First. *Briton.*	Second. *Briton.*	Third. *Briton.*
Built	1854	1861	1897
Length, feet	162.5	248.0	530
Breadth, feet	23.2	30.7	60
Depth, feet	16.9	23 9	40
Gross tonnage	491	1,163	10,300

Reindeer and **Roebuck.**—These two steamers, built by the Naval Construction Company of Messrs. Vickers, Sons & Co., Barrow, for the Great Western Railway Co., and described on page 868 of Volume VIII, have made their trials. The *Reindeer* was launched on May 1, and the *Roebuck* some time before this.

The vessels were required to maintain a speed of 20 knots for three and one-half hours. The mean of four runs over the measured mile gave 20.25 knots for the *Roebuck*, and over 20 knots for the *Reindeer*. Both trials were successful.

The vessels will carry about 600 passengers. The boilers are fitted with Howden's forced draft system.

Sorato.—This steel steamer, built by Messrs. C. S. Swan and Hunter, Wallsend, for the Pacific Steam Navigation Co., was launched in February and completed her trials on April 14. She is a duplicate of the *Corcovado*, described on page 865 of Volume VIII.

The length over all is 405 feet; beam, 47.25 feet; depth, 32.75 feet; deadweight carrying capacity, about 6,600 tons. There are three steel decks and seven main watertight bulkheads. The double bottom, which extends the whole length of the vessel, has ten longitudinal subdivisions.

The engine is of the triple expansion type, with cylinders 24, 40 and 66 inches in diameter, the stroke being 51 inches. There

are three cylindrical boilers, the working pressure being 190 pounds per square inch.

On the trials the vessel carried a load of about 4,400 tons, and attained a mean speed of 12.54 knots for the four hours' run and 12.9 knots on the measured mile.

Wreathier.—This steel steamer, built by Messrs. Craig, Taylor & Co., Thornaby-on-Tees, for the Goole & West Riding Steam Shipping Co., made her trials on May 4. The following data are from the "Engineers' Gazette," London.

The length is 208 feet; beam, 31 feet; and depth, 13 feet 7 inches. The machinery was built by the Wreath Quay Engineering Works, Sunderland. The engine is of the triple expansion type, with cylinders 17, 28.5 and 46 inches in diameter, the stroke being 30 inches. There is one steel boiler, 14 feet in diameter and 10.5 feet long, with a working pressure of 160 pounds per square inch.

On May 4, a mean speed of 14 knots was made on the measured mile runs, the I.H.P. being about 804.

A run between the Tees and the Tyne was accomplished at a speed exceeding 12 knots against a strong tide. The boiler efficiency was very high, as with ordinary coal and without forcing the fires, 12.7 I.H.P. were developed per square foot of grate surface, and 1 I.H.P., for 2.23 square feet of heating surface. The machinery worked perfectly, there being no signs of vibration or heating at any part, and no water being used on any bearings.

Jupiter.—This oil tank steamer, built by Messrs. Wm. Dobson & Co., Newcastle, for Messrs. Lane & Macandrew, London, was launched on April 14 and made her trial on May 10.

The length is 275 feet; beam, 32 feet; depth, 19 feet 8 inches. As the vessel is intended for service on the Volga river, she is built in two sections which can be separated and again connected afloat, when passing through the Russian canals. Special pontoons are built and sent out with the vessel to keep her in trim during this operation.

The twin screw engines, built by the Wallsend Slipway & Engineering Co., Newcastle, are of the compound type, with cylinders 24 and 46 inches in diameter, the stroke being 27

inches. There are two cylindrical boilers, each 14 feet in diameter and 12 feet long, fitted for burning oil as well as coal.

On the trial on May 10, a speed slightly greater than 11 knots was attained on the measured mile runs.

Pointer and **Spaniel.**—These steel coasting steamers were built by Messrs. A. and J. Inglis, Glasgow, for Messrs. G. and J. Burns' trade from the Clyde to Belfast, Liverpool and Manchester. The following detailed description of one of the vessels is from "Engineering," London.

The length on keel is 250 feet; greatest beam, 33.5 feet; depth, 17 feet 2 inches; sheer, forward, 4.5, aft, 1.75 feet; length of poop, 70, of forecastle, 47, and of hurricane deck, 77 feet; height between all decks, 6.75 feet.

The difficulties of combining satisfactory sleeping and dining accommodation without both being unpleasantly associated, have been overcome by putting the saloon in a house aft, while the staterooms are on the deck below. Deep bilge keels are fitted. The keel and stern are of hammered scrap iron, the stern post is in one piece, the rudder post being carried to the main deck in one piece, and the frames throughout the ship are carried up to the level of the poop and forecastle right fore and aft, the wells having high bulwarks. In the wake of the engines, reverse bars $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{10}{20}$ inch have been used. The plating throughout is $\frac{7}{20}$ inch, slightly increased in the machinery spaces, and $\frac{9}{20}$ inch at the topgallant forecastle deck. The garboard strake is 36, and the sheer strake, 55 inches broad with outside straps. All butt straps are inside. There are bulkheads with $\frac{8}{20}$-inch steel plating, forming seven watertight compartments.

The first class cabins have patent folding berths of iron, with spring and chain mattresses. The dining saloon is 42.5 by 15 feet, and is fitted up in a handsome manner. One feature of the design is the arrangement of side tables and settees, enabling parties of two or three to dine together. The saloon is well lighted by a skylight overhead, and by large rectangular brass-framed windows along each side. A commodious pantry is placed at the forward end of the saloon. Abaft the saloon is the

companion house, covering the stair leading to the staterooms. There is a well-lighted and ventilated smoking room, 17.25 by 21.25 feet, on the bridge deck. Under the forecastle deck, an open steerage is fitted up for the shelter of deck passengers, and a portion of the main deck is set apart for their use. A bar and refreshment room is fitted up under the forecastle. The crew are berthed in a forecastle below the steerage, and the officers on the main deck, partly forward and partly amidship. The engine and boiler casings are carried up above the bridge deck to the boat deck overhead, thus providing an uninterrupted and protected promenade. There are six boats, two being cutters. The galley is placed in the boiler casing

Cattle stalls have been provided on the main deck between the forecastle and poop. There are three deck winches, each with 7-inch cylinders and a stroke of 12 inches, besides the usual windlass and anchor hoist on the forecastle.

The engines are of the triple expansion type, with the starting platform on the port side. The cylinders are 24, 39 and 64 inches in diameter, the stroke being 42 inches. The piston clearance at the top is $\frac{1}{4}$, and at the bottom, $\frac{3}{4}$ inch. The cylinder barrels are $1\frac{3}{4}$ inches thick at the sides and $2\frac{1}{4}$ inches at the bottom, with $1\frac{3}{4}$-inch liners. The covers are 10, and the casing covers, 6 inches deep. The pistons, 10 inches deep, are of cast iron and hollow, with strong ribs, the H.P. being provided with Ramsbottom rings, while the I.P. and L.P. have Lockwood and Carlyle's fittings. The rods are $6\frac{1}{4}$ inches in diameter, with $7\frac{1}{2}$-inch collars, the guide block faces being of Babbitt metal, with 250 square inches of surface. The connecting rod is forged, 8 feet long, 7 inches in diameter at the bottom and 6 inches at the top, with $3\frac{3}{4}$ and $2\frac{3}{4}$-inch pins. The H.P. valve is of the piston type, fitted with Buckley's packing rings. The I.P. slide valve is of Trick's, and the L.P. of Thom's design, the travel in each case being $6\frac{1}{2}$ inches, while the spindles are $3\frac{1}{2}$ inches in diameter. The L.P. valve has a balanced piston.

The crank shaft is in three interchangeable sections, each bearing being 16 inches long and $12\frac{1}{2}$ inches in diameter. The pins are $14\frac{1}{2}$ inches long. The propeller shaft is $12\frac{1}{2}$ inches in

diameter, but the tunnel shaft is 12¼ inches and in 15-foot lengths, having 18-inch bearings. The thrust shaft has 14 collars, giving .75 square inch of bearing surface per I.H.P.

The surface condenser has tubes ¾ inch in external diameter, with brass end plates, having 1⅛-inch stays. The circulating pumps have 12-inch cylinders with 40-inch vane. The air pumps are driven from the I.P. crosshead, with a pump to Weir's feed heater on one side and a bilge pump on the other.

There are two single-ended boilers, 14.5 feet in mean diameter and 12 feet 4 inches in length, working at a pressure of 150 pounds. Each has three of Morison's corrugated furnaces, 8 feet long by 3 feet 5 inches in mean diameter, rounded up at the back tube plates to a radius of 4 inches, and with separate fire boxes to each furnace. The furnace bars are in two lengths, each 3 feet long, 4 inches deep and ⅞ inch wide. The grate surface is 117, and the heating surface, 3,754.8 square feet. The tubes are of iron, 3¾ inches in diameter, the spaces between the nests of tubes being 12 inches. The funnel is 7.5 feet in diameter and is 39 feet high above the hurricane deck. There is an unusually tall donkey boiler in the stokehold between the two bunkers. It is 20 feet high and 6.5 feet in mean diameter. The fire box and water tubes are of Staffordshire BB iron and welded. The ten water tubes are 10 inches in diameter and $\frac{7}{16}$ inches thick. The water space around the fire box is 10 inches at the top and 6 inches at the bottom, the total heating surface being 271.3, and the grate surface, 22.5 square feet. The working pressure is 70 pounds per square inch, suitable for the deck machinery. There are two Weir's feed pumps in the engine room.

Caldwell's steering gear and the electric lighting plant, which consists of a Chandler's engine, driving direct at 300 revolutions a Harvey dynamo, compound-wound, are fitted on platforms in the engine room. There are about one hundred 16, and seven 50 candle power lamps.

The bunker capacity is 100 tons of coal. The vessel has one smoke pipe and two masts. The crew numbers 35.

The contract speed test, which has been maintained in service, consisted of six runs between the Cloch and Cumbræ Lights, with the vessel drawing 11.25 feet forward and 13.75 feet aft, with the boilers full, 50 tons of coal in the bunkers, 270 tons of pig iron distributed throughout the ship, while the cargo capacity was to be 45,000 cubic feet. The speed was to be 13¾ knots. The weight was carried with something of draught to spare, and, with a four-bladed propeller, 13 feet in diameter, 20 feet pitch and 68 square feet of surface, a mean of 14.4 knots was attained. The separate runs were 14.6, 14.2, 14.3, 14.5, 14.1, 14.5 knots. The mean number of revolutions was 82, and the I.H.P., 1,840.

YACHTS.

Mayflower.—This steel twin screw yacht, partially described on page 210 of the February number, has completed her trials. The following additional description is from "Engineering," London.

The hull is divided by eight steel watertight bulkheads. There is a short forecastle and a long bridge, the latter extending two-thirds of the vessel's length, and separated from the forecastle by a short well or break deck, the side plating being carried in an unbroken line from knighthead to the after end of the bridge, where it drops down about four feet to the level of the main deck bulwarks and continues at this line to the taffrail. A length of 75 feet at the stern is thus at a lower level than the remainder of the sheer, the change of line being cleverly broken by supporting the aftermost 30 feet or so of the bridge deck upon stanchions, in place of carrying the side plating right up. The depth of the vessel, from keel to bridge deck at the side, is 30 feet.

The main gangway is a doorway, 3.5 feet wide by 7 feet high, cut through the starboard side of the yacht above the main deck, and is covered outside by a watertight steel door, and inside by a door of paneled oak, which admits into a palm-decked reception room arranged around the engine casings. These casings have been converted into a beautiful gallery filled with large clear plate glass windows, framed in richly-wrought iron and brass work, which not only give light and air to the reception room, but also afford an opportunity of watching the engines.

Aft of this reception room is the drawing room, 21 feet long and 32 feet broad, extending from side to side of the vessel. The decks here are 9 feet apart. Leaving the drawing room, we pass the head of a stair leading down and enter the library, of carved oak, built under the aftermost portion of the bridge deck, and lighted on three sides by large rectangular windows.

As this room does not occupy the whole of the vessel's breadth, doorways from it and from the stairhead previously mentioned, lead to sheltered passages between the library and the main deck bulwarks and under the overhanging portion of the bridge deck. Still further aft, and free from the protection of the bridge deck, are a skylight and secondary stairway to the cabins below, companion to sleeping quarters for six valets, and a spacious stern grating over a steam warping capstan and steam and hand steering gear. This gear is controlled from the bridge and wheel house by means of light wire ropes carried under the main deck.

Descending by the after stairway to the guests' accommodation, we find six large and airy staterooms, doctor's room, maid's room and two bath rooms. These rooms are all paneled solidly in mahogany, everywhere covered with five coats of white paint wrought up to a beautiful enameled surface. A large ventilating trunk, concealed in the cornices, is carried through all these apartments, with a louvre to each room, whereby ample ventilation may be secured at will.

Ascending to the main deck by the forward stair, we retrace our steps through the drawing and reception rooms, and, proceeding forward, we enter the dining room, which is situated between the engine and boiler casings, extends the full width of the ship, and measures 36 feet by 22 feet. The paneling is of beautifully-carved oak of antique design and dull finish. The room is lighted by means of ten 14-inch side lights and two skylights arranged alongside a deck house above.

At the foot of a narrow flight of stairs from the dining saloon is the steward's store, and, passing through an air lock with double doors 10 inches thick, we enter the refrigerating chambers, all lined with white tiles and occupying a total space of 18 by 12 feet.

Passing further forward we enter the saloon pantry, beautifully tiled in white, and extending from the ship's side to the funnel casing, with an exit at its fore end leading to the port or servants' passage. On one side of this are the servants' stair to the bridge deck, and four well-ventilated drying rooms heated from the funnel uptakes, while on the other side we pass the cold room and

bakery, and come to the saloon galley, with white tiles on the floor and the walls and well ventilated. Forward of the galley is a laundry.

From the starboard side of the dining room a door admits to a small octagonal smoking room, and to the starboard or guests' passage, which is paneled in mahogany and painted white. It is lighted and ventilated by means of a long skylight which runs the whole length of the boiler casing, and contains a number of bullseye lights and cowl ventilators. A similar skylight also overlies the port passage. The starboard passage gives access to a lavatory and bath room and three small staterooms, and leads at its forward end to the main stairway and owner's apartments.

The latter are situated under the fore end of the bridge deck, and have large rectangular windows looking out on the break deck between the bridge and forecastle. These quarters consist of two large staterooms, with adjoining bath rooms, and a boudoir, all on the main deck; a ladies' boudoir on the weather deck above; and a roomy cabin and bath room on the deck below. Close by, on the lower deck, are servants' rooms.

Ascending the forward stair, and passing the deck boudoir in the forward deck house, we emerge upon the bridge deck, an unbroken promenade of 190 feet long and 10 feet wide upon each side of the vessel. The central portion of the deck is taken up by funnel casings, which are covered with paneled work in teak and gratings. Upon these casings stand the sanitary water supply tanks under the guise of skylights, and lockers for rugs and boats' cushions. Four comfortable seats are recessed into the sides, and from the fore end a broad and easy flight of steps ascends to the top of the forward deck house and bridge. At the after end of the casings and over the dining room stands a deck house containing a large smoking room in teak, and the after vestibule, with its broad stair leading down to the reception room. Aft of this house, the spacious deck is broken only by two low engine room and the drawing room skylights. The most striking features of the promenade deck are the two large deck houses, the teak wood of which is simply flawless.

The officers' quarters are forward, below the break deck. The mess room, 20 by 10 feet, is panelled in polished ash and occupies the center of the ship, with rooms for thirteen men on its sides. An officers' pantry and bath room are also provided. Forward of the mess room are rooms for twelve petty officers, and below, large store rooms for crew and carpenter, a carpenter's workshop, steel ammunition room, tanks for storing no less than 45 tons of fresh water, and a subterranean passage leading through the coal bunkers to the stokehold. In the forecastle also are arranged the crew's galley, lamp room, petty officers' bath room, &c., while below is a large and airy dormitory and mess room for twenty-two seamen, and still lower, the crew's lavatory and bath room.

The valves of the H. and I.P. cylinders are of the piston type, the L.P. cylinders being fitted with Thom's patent slide valve; all the valves are balanced, and the valve gear is of the double eccentric and link motion type. The reversing gear is controlled by Brown's combined steam and hydraulic engine, and the levers of the reversing shaft are fitted with screw gear to allow of the expansion in each cylinder being altered independently of the other. The cylinders are supported at the front by wrought steel columns, and at the back by columns cast with the condenser. The circulating pumps are of the centrifugal type. An evaporator, distiller, feed water filters and auxiliary condenser are installed. Besides these, there are in the engine room two Weir's feed pumps, one auxiliary steam pump, two bilge donkey pumps, one sanitary pump, one fresh water pump, two sets of electric light machinery and one set of refrigerating machinery.

The screw propellers are three-bladed, the bosses being cast steel and the blades of manganese bronze and adjustable.

Steam at 160 pounds pressure is generated by two large single-ended boilers with four furnaces in each, worked under the closed ash pit system, the air being supplied by two large fans. The donkey boiler is of the vertical type, working at 90 pounds pressure, and is of ample power to provide steam for all the auxiliary machinery. There is a feed pump in the stokehold for supplying the donkey boiler. A separate system

of main steam piping has been led from each boiler to the engine room and there connected by common stop valves, so that the engines may be worked by either boiler in the event of an accident to either system of piping. The coal capacity is 530 tons.

Nine boats are carried, including a 32-foot steam launch and an electric launch.

The trials consisted of progressive, coal consumption and the official speed trials. On the latter, made in the Firth of Clyde, a mean speed of 16.75 knots was obtained with 4,650 I.H.P.

Hiawatha.—This yacht, mentioned on page 446 of the May number, made a successful trial on the Hudson river on May 28. The contract speed was 17 miles per hour.

The trial was made under natural draft with a steam pressure of 195 pounds per square inch, the speed for three hours being over 18 miles per hour.

Punjaub and **Raynham.**—These yachts were built from the the same model at the shipyard of the Gas Engine and Power Co. and Charles L. Seabury & Co., Morris Heights, New York. The *Raynham* was launched in June.

The following description is from "Seaboard," New York.

The length over all is 85, and on the water line, 72 feet; beam, 13 feet; draught, 5 feet; estimated speed, 15 miles per hour. They are flush deck from stem to stern, with bulwarks and rail, and schooner-rigged. Each has a fine mahogany house on deck forward, the lower part of which is paneled and the upper part fitted with heavy plate glass, arranged to slide up and down.

The owner's quarters are forward, and consist of two very large staterooms with double berths. The saloon is large and roomy and fitted with transom berths. These quarters are handsomely finished and furnished. The crew's quarters and galley are aft of the engine and boiler room. The triple expansion engine has cylinders 7, 11 and 17 inches in diameter, the stroke being 10 inches, and is designed to develop about 200 horse power. The steam is supplied by a Seabury water tube boiler, with a working pressure of 260 pounds per square inch.

Vergana.—This steel yacht, built by Messrs. T. S. Marvel &

Co., Newburg, N. Y., from designs by Messrs. Gardner & Cox, New York, for Mr. F. H. Benedict of New York, was successfully launched in June.

The following particulars are from the "American Shipbuilder," New York.

The length over all is 147 feet, and on the water line, 117 feet; beam, 18.5 feet; depth of hold, 11 feet; draught, 7.75 feet. There are two deck houses, the forward one fitted as a dining room, 22 feet long and 11 feet wide, and the after one as a social hall, 18 feet long and 11 feet wide. The bridge is on the after end of the forward house.

Both houses are of polished mahogany, inside and outside, and all deck fittings are of the same material. The upper and lower rails are of teak. The deck space will be large, the distance from the after end of the social hall to the taffrail being 38 feet or more. Forward on the deck below is the forecastle, which will have comfortable and ample accommodation for eight men. The rooms for the captain and chief engineer come next; then follows the officers' mess room, with four berths, two on a side, and a center table; next, the galley, which extends across the vessel, and will be given complete fittings of a modern character, and have electric fans for ventilation. Aft of the machinery space come the owner's quarters, which occupy the entire width of the vessel. These consist of two large, double staterooms, each 10 feet long, and a private bath room of 5 feet 4 inches. The staterooms will have large double berths and be fitted with sliding doors, so that they may be used separately if desired. All the pumping in the bath rooms will be done by electricity. Next aft of the owner's rooms is the saloon, 12 feet long by 16 feet wide. Aft of this are three staterooms, two on the port, and the other on the starboard side. The extra space on the starboard side is for a ladies' bath room and lavatory. Then comes a double stateroom for ladies, which, like the other rooms, is handsomely furnished. The finish of the several staterooms will be in different tints of white, mauve, pink, blue and yellow. The ladies' room will be in rose pink.

The engines are of the triple expansion type, with cylinders

9, 16 and 25 inches in diameter, the low pressure cylinder being in the center, and a stroke of 16 inches. Two Almy water tube boilers will supply the steam. There will be four boats, two being Alco vapor lauches, one a life boat, which may be used as a cutter, and the fourth, a dinghy.

Rosabelle.—This composite yacht, described on page 448 of the May number, made 12 knots on her trial on June 5.

Andria.—This steel yacht, described on page 449 of the May number, completed her trials on May 22.

On the runs between the Cloch and Cumbræ Lights on the Firth of Clyde, a mean speed of 14.66 knots was obtained, the distance being about 31.5 nautical miles. The steam pressure was 175 pounds per square inch; revolutions per minute, 159; I.H.P., 1,200.

The vessel has one single-ended, three-furnace boiler, 14 feet in diameter and 10.5 feet long. The coal capacity is 70 tons.

Tuscarora.—This yacht, built by Messrs. Scott & Co., Greenock, Scotland, for Mr. Wm. Clark, from designs by Mr. G. L. Watson, was launched on June 17.

The length is 180 feet; beam, 26.5 feet; depth, 15.5 feet; tonnage, 570, yacht measurement.

There is one triple expansion engine, designed to develop 1,000 I.H.P.

Ellide.—This composite yacht, designed by Mr. C. D. Mosher, of New York, and described on page 447 of the May number, made an unofficial trial under forced draft on the Hudson River in June.

The published accounts give a speed of 31.9 miles per hour for the run over the mile. Efforts are being made to have the official trial run soon under naval conditions.

The contract requires a speed of 30 miles per hour, the owner agreeing to pay a bonus of $1,000 for every mile above this speed.

BOOK REVIEW.

THE ENTROPY-TEMPERATURE ANALYSIS OF STEAM ENGINE EFFICIENCIES. By Sidney A. Reeve, M. E.—The entropy-temperature diagram is an easy and simple method of solving, graphically, engineering problems in thermodynamics. By combining it with the indicator card of a steam engine, a complete account of the transfer and distribution of all the heat involved in the cycle of the engine will be obtained. This the indicator card, alone, does not give.

The great difficulty with this method has been the labor involved in constructing curves for each case under investigation. Mr. Reeve has removed this by having printed blanks that will suit for almost all cases. His book contains also an explanation of the diagram and its principles, and a set of definite, practical instructions for its use. It is a most practical work on this subject and would be a valuable addition to an engineer's library. In conjunction with this book, it would be well to read "Temperature-Entropy Diagrams for Steam and Water," by L. M. Nulton, Passed Assistant Engineer, U. S. Navy, Volume VII of this JOURNAL, and also "The Steam Engine and Other Heat Engines," by Professor J. A. Ewing. Both of these are simple and require only the most elementary knowledge of mathematics.

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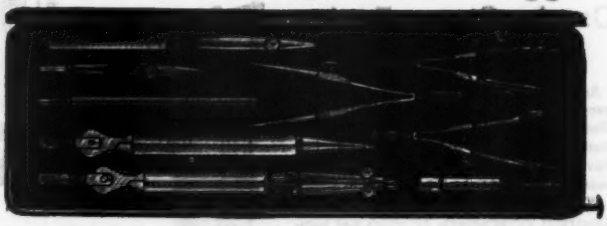

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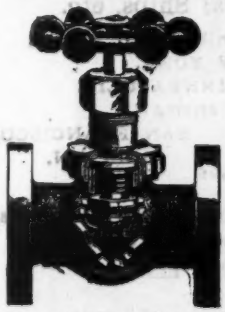

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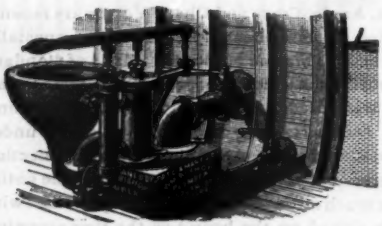

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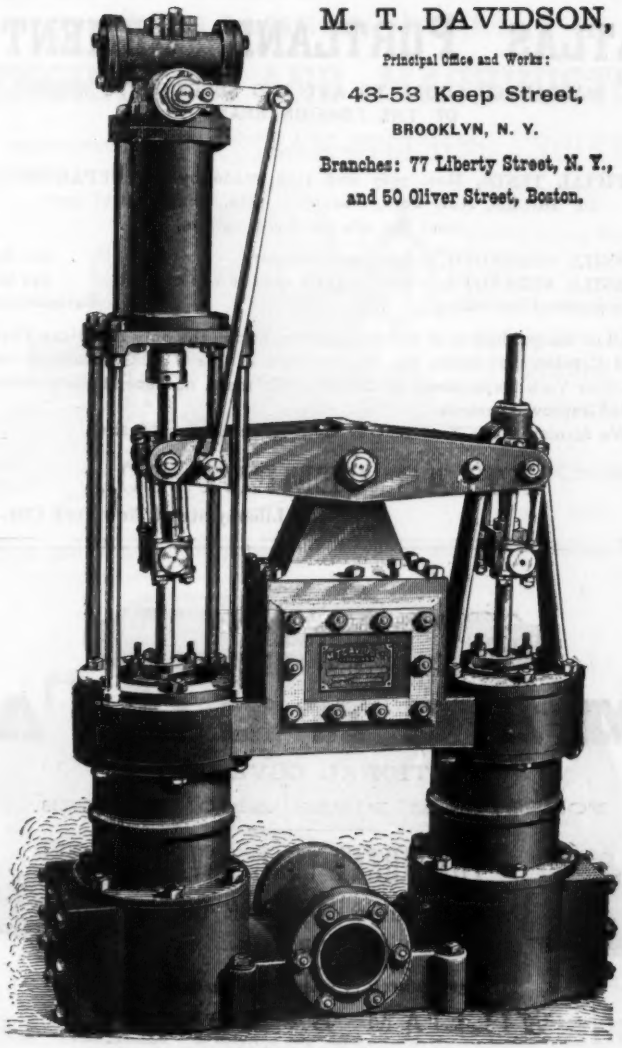

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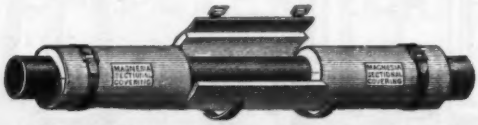

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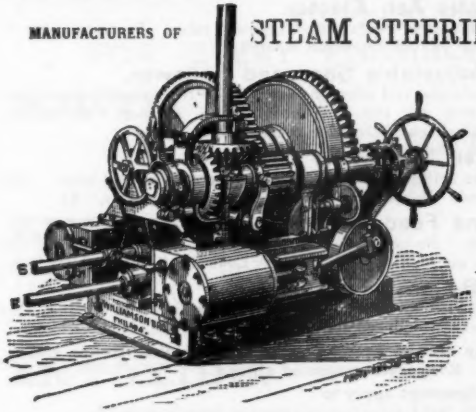

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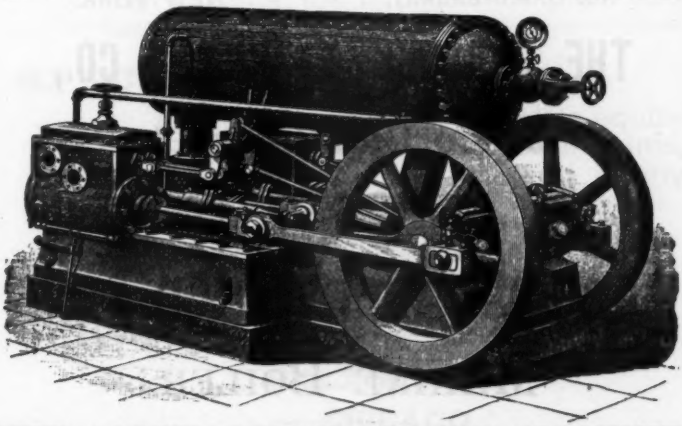

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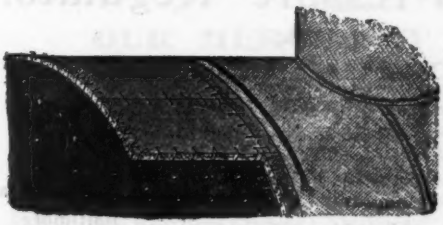

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RAM.

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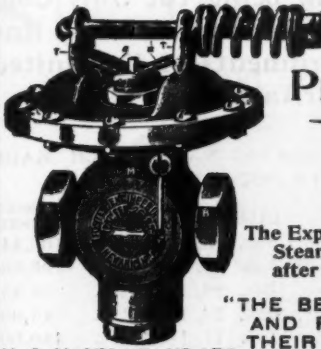

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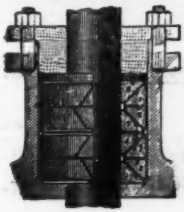

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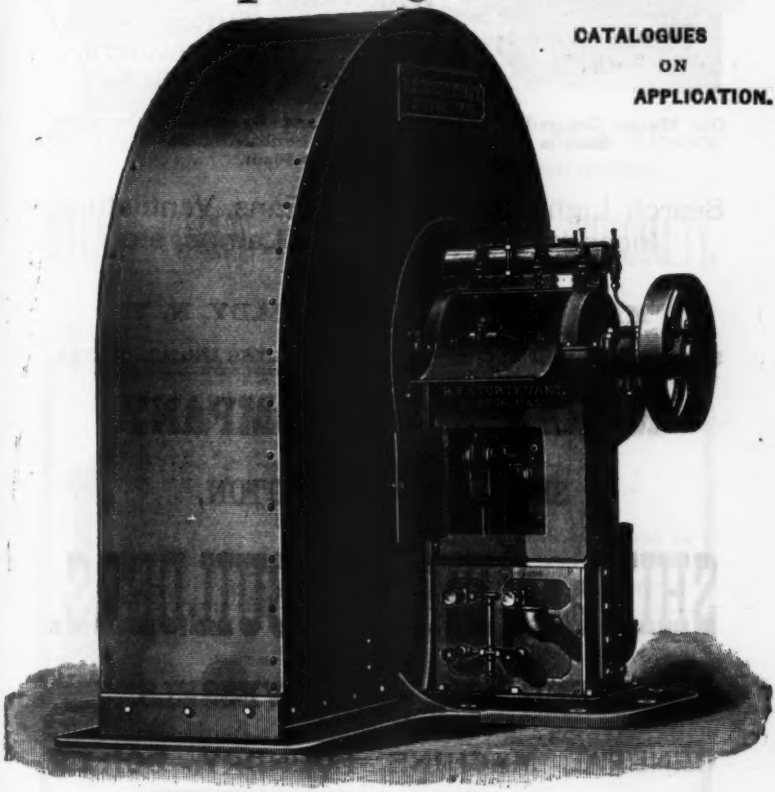

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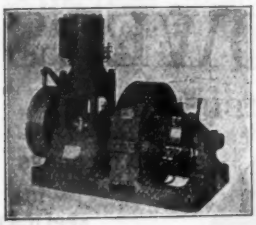

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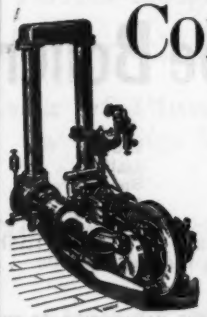

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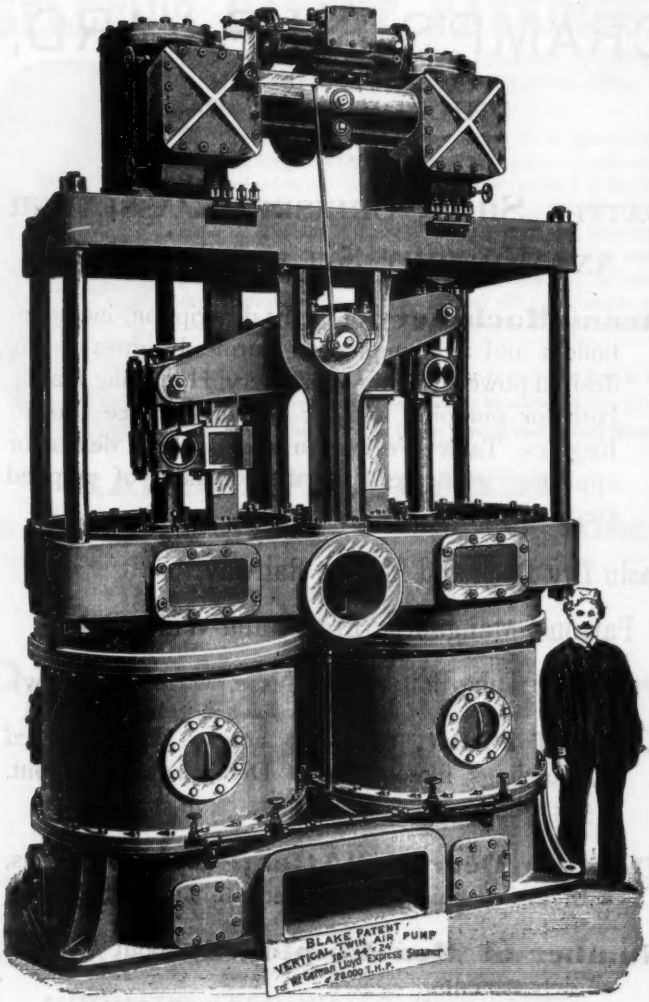

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NOTICE.

The Annual Meeting of the Society will be held in Washington, D. C., on January 7 and 8, 1898. It is proposed to devote the first day, Friday, to the reading of papers and to the transaction of business, and the second day, Saturday, to social functions and a dinner in the evening. The detailed programme will be mailed later. The Council hopes that the attendance of members and associate members will be large, so that the success of the meeting and of the first annual dinner may be assured.

Members and subscribers are respectfully notified that the **annual subscription of $5** for the JOURNAL **for the year 1898** is now due, and that prompt payment will be a favor to the Secretary.

It is requested that any change in the address of members, subscribers and exchanges for the coming year be communicated to the Secretary and Treasurer before January 1, 1898.

Respectfully,

F. C. BIEG,
Secretary and Treasurer.